THE ENGINEER

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The Chatham Bus Accident Inquiry

THE Engineers' Guild has written to the Minister of Transport welcoming the Government's proposal to arrange for a public inquiry into the distressing bus accident at Chatham on December 4th, when twenty-four Royal Marine cadets regrettably lost their lives. In the letter to the Minister the Guild has expressed the opinion that the customary arrangements for the investigation of highway accidents are inadequate, and support is promised for any measures designed to effect improvement. The letter points out that, for many years, it has been the practice to appoint an engineer to conduct inquiries into railway accidents and suggests that the technical considerations involved in highway transport are as complex and no less important than those pertaining to rail transport. It is submitted, therefore, that only a professional engineer experienced in these matters is competent to appreciate fully the relevant facts revealed through the giving of evidence. On that account, the council of the Guild has urged that the person appointed to conduct the proposed inquiry should be a professional engineer with experience of highway and traffic matters.

Cost of Ships

AT the annual dinner of the Glasgow Shipowners' and Shipbrokers' Benevolent Association, held last week, Mr. Hull, the chairman of Ellerman Lines, Ltd., proposed the toast of the Association and discussed the high cost of new ships, taxation relief and the industrial canker of unofficial strikes. The current prices for ships, he said, were twice those obtaining in 1945 and comparison with 1939 was reminiscent of a bargain counter. He repeated, what has been said so often before, that profits earmarked for tonnage replacement programmes should not be taxed or fleets could not be maintained at full strength. This possibility was not appreciated by those people who only noted the present boom in shipbuilding, and high freight earnings, but, Mr. Hull said, this was the crest of the wave which must be followed inevitably by a trough. When the flow of trade ebbed and earnings fell the shipping companies had to carry on by using funds put aside, for just such a purpose, while earnings were high. Referring to unofficial strikes, he deplored the present-day indiscipline and the refusal to use labour-saving devices, quoting as an example of this short-sighted policy, a new elevator representing considerable capital investment, which now lay idle. Such practices would bring about eventually a reduction in our trade which would be finally brought to a standstill if overtime was banned and go slow tactics were maintained. Mr. Hull was appalled at the way the nation was beginning to accept the second best and pointed out that the former prosperity of Britain was not an accident, but resulted from honest endeavour.

The Chairman of the Gas Council

IT has been announced that Colonel Harold C. Smith, C.B.E., is to succeed Sir Edgar Sylvester, K.B.E., as chairman of the Gas Council on January 1st next. Colonel Smith, it will be remembered, was appointed deputy chairman designate of the council on April 14, 1948, and the appointment was formally confirmed after the passing of the Gas Act in July, 1948. He is also the chairman of the Gas Research Board and a member of the Scientific Advisory Council appointed by the Minister of Fuel and Power. After serving in the first world war from 1914–1919, and being commissioned in the Royal Field Artillery, Colonel Smith joined the Tottenham and District Gas Company as works superintendent in 1920. Two years later he became chief engineer of that company, general manager one year after, managing director in January, 1946, and deputy chairman in the November of that year. From 1947 till 1949 he was chairman of the British Gas Council, and for many years chairman of the London and Counties Coke Association and other bodies concerned with solid smokeless fuels. He became chairman of the Federation of Gas Employers in succession to the late Sir David Milne Watson in 1943. He is a member of the Institution of Civil Engineers and was president of the Institution of Gas Engineers in 1937–38.

Industry in London

THIS week, the London County Council has had before it the report of its Town Planning Committee on the Administrative County of London Development Plan, 1951, which makes comprehensive proposals for co-ordinating the development of London over the next twenty years. A detailed analysis of the plan has been prepared to assess the various problems brought to light by about thirty surveys of London's physical, economic and social conditions. An important section of the Town Planning Committee's report on the plan is that dealing with industry. It admits that the decentralisation of industry is probably the most difficult of all planning problems. The report says that the need for decentralisation of places of employment to match that of population is obvious, yet in practice is very difficult to achieve, chiefly because of present economic conditions and the inevitably high cost. The committee's opinion is that, so far as proves practicable, such land in the Administrative County of London as is available for industrial development should be used for the accommodation of industry already inside the administrative county and should not be available for industry coming in from elsewhere. But, the report notes, so difficult are the problems raised by the whole subject of decentralisation of industry that national policy is involved. The report explains that, in the Plan, about 4102 acres have been zoned for industry, as compared with 4111 acres now so used. About 1460 acres of existing industry are located in residential and ancillary zones, and most of it, the report states, can be regarded as "non-conforming." Of those 1460 acres, it is suggested that about 1170 acres could be accommodated in industrial zones, leaving about 290 acres to be decentralised outside the county boundary.

Engineering Training

AT a meeting of the Junior Institution of Engineers which was held in London on Friday evening last, Air Commodore F. R. Banks, C.B., M.I.Mech.E., F.R.Ae.S., was installed as president for the year 1951–52. His presidential address, which was delivered after the installation ceremony, was entitled "Enterprise in Engineering," and in the course of it Air Commodore Banks made several observations on the subject of engineering education and training. To-day, he said, an engineering degree from one of the universities was considered essential, but he considered that a university degree was only the start. It was, in fact, very similar to the granting of "wings" to a pilot; a degree qualified the man to obtain experience in his profession. Air Commodore Banks then spoke of the case of the man with inherent engineering ability who was unable to pass examinations, saying he did not think that kind of man was sufficiently considered or catered for to-day, especially in view of the fact that there was always a shortage of good men. In his young days, Air Commodore Banks recalled, and particularly in the earlier days of those somewhat older, it was more important to have served a practical engineering apprenticeship of at least five years than to have academic qualifications. The greater technical knowledge of to-day, however, compared with that of forty years ago, was such that a much higher standard of education was necessary in order to meet modern requirements. Air Commodore Banks therefore suggested that it should be the responsibility of industry, the universities and the technical colleges to get together and try and hammer out an engineering curriculum which had as its basis a good mixture of practical engineering and technical or theoretical instruction. Thus, the man who was unable to pass the academic requirements for a B.Sc. degree could take a simpler and more practical test and obtain a certificate qualifying him to enter a firm to start an engineering career. With equal opportunity, if he grasped it, and continued theoretical training, there was no reason why such a man should not do as well as his more academic brother.

Potato Harvesting Machinery Competition

THE Royal Agricultural Society of England has now stated that twenty-five entries have now been finally approved for the potato harvesting machinery competitition which it first announced about two years ago. The object of the competition is to encourage the more complete and effective harvesting of potatoes by machinery and so reduce dependence on hand picking. The competition was open to both British and foreign machines, each of which was subject to inspection this season to ensure that untried prototypes were not submitted for trial next year. To qualify for acceptance, the entries had to consist of a machine, or group of machines, undertaking the full sequence of operations from lifting potatoes from the ridge to depositing them direct into bags or a bulk container on the machine, or to a transport trailer travelling with it. The trials of the machines accepted for the competition will be held during next year's potato harvest in the West Midlands and Cambridgeshire. The West Midlands trials will be conducted on moderately stony and sandy soil, and in Cambridgeshire there will be two trial sites, one on a heavy fen soil and the other on light stone-free land. After an adequate period for setting and adjustment, every machine entered will undergo set tests of two or three hours' duration, during which measurements of output and efficiency will be taken. Performance marks will be awarded for output per man-hour, taking account of such aspects as damage to the crop and cleanliness of sample. Marks will also be allotted by the judges in respect of convenience in operation, accessibility for maintenance, and soundness of design and construction, while another matter which will be taken into account is the price of the machine in relation to its performance. The Royal Agricultural Society says that four of the twenty-five machines accepted for the competition are foreign, two coming from Sweden, one from Denmark and one from Holland.

The End of an Era

BY EDWARD H. LIVESAY

No. VI—*(Concluded from page 753, December 14th)*

THE foregoing parts of this article described the steam locomotives at present working through the mountainous country between Vancouver and Calgary, and the work they do, so a concluding article may appropriately be given to the diesel-electric power that will soon displace them. It will be advisable first to outline what has already been done elsewhere on the Canadian Pacific system, as the experience gained was satisfactory enough to justify the company extending its diesel programme to other parts of the line, and will lead in the not very distant future to the ultimate total disappearance of the steam locomotive. "'Tis true 'tis pity, and pity 'tis, 'tis true," but the "basic design" steam engine admirer must make up his mind to it.

FIG. 31—2250 H.P. DIESEL-ELECTRIC LOCOMOTIVE

The first part of the C.P.R. system to be worked entirely by diesel-electric locomotives was the Esquimalt and Nanaimo Railway, on Vancouver Island; this was dealt with in THE ENGINEER in the concluding numbers of 1950. At the same time, tentative running was being done in other parts of the country, and in the eastern States into which C.P.R. tentacles have reached. The Boston and Maine Railway, for instance, a subsidiary of the C.P.R., began using 2250 h.p. "E 8" twelve-wheel single-unit engines in 1949 on its Montreal–Wells River (Vt.)–Boston trains, the General Motor Company, of La Grange, Ill., being responsible for the locomotives; they are illustrated by Fig. 31. These trains, the well-known "Alouette" and "Red Wing," were the first in Canada to be hauled by diesel-electric engines especially designed for passenger service, the change-over on this important international link beginning about three years ago. The engines are geared for 85 m.p.h. and embody various technical improvements that include increased steam-heating capacity with two boilers. Freight trains are also hauled over the same divisions by two-unit 3000 h.p. engines, and they were also put into service over the rugged stretches north of Lake Superior, between Fort William and Cartier, forty-four units being built by the Montreal Locomotive Company and fourteen at the new plant of General Motors Diesel, Ltd., London (Ont.); they are shown in Fig. 32. These fifty-eight units have replaced sixty-eight steam locomotives, and complete the "dieselisation"* of the 517-mile Schrieber division, situated in one of the coldest parts of Canada. White River, for instance, has long been infamous as a place where ultra-low temperatures can be looked for every winter. However, White River has since lost this distinction, 72 deg. below zero having been recorded at Iroquois Falls in Northern Ontario during the winter of 1935, and 83 deg. below zero, Canada's low temperature record, at Snag, in the Yukon, two winters ago—a figure that surely has never been beaten except in Siberia.

The sixty-eight displaced steam locomotives are now serving out their lives elsewhere on the company's system, an example of merely one of the economies that are expected to follow from the change-over. When summer navigation begins on the Great Lakes, diesel operation will be extended farther east, to Chapleau and MacTier, in Ontario, and probably to Toronto and Montreal ultimately. Some of this running may already have taken place without my personal knowledge or observation, a recent Vancouver–Montreal journey having been made over the Canadian National route.

Where climatic conditions are as extreme as, of course, they are in many parts of Canada, ranging from 50 deg. below zero in winter to 100 deg. in the shade in summer, the engines have to be built to the specifications that the C.P.R. has found by experience to be necessary to cope with these "peak" temperatures. It is during the winter, when parts of the Great Lakes and their canal outlets—such as the Soo and Welland—are frozen over, that the railways have to transport the prairie wheat crop that pours in a golden flood into the Fort William elevators and others farther east, at Buffalo, and so on. It is then that rail traffic is at its maximum, and the ability of the multi-unit diesel engines to handle greater tonnage than their steam contemporaries is of especial value, enabling the flow of traffic over single lines to be increased, particularly in sub-zero weather when the efficiency of steam locomotives drops considerably, but diesel power is not affected, at any rate, to the same degree.

These fifty-eight units cost £4,000,000 and were among the first to be built in Canada. The Montreal Locomotive Company's machines were based on the Alco prototype, the General Motors' design being based on those built at La Grange (Ill.); actually, there is probably little difference between them. This is the largest order for diesel locomotives so far placed by a Canadian railway, and it marks the inauguration of a new Canadian industry. The expenditure of this large sum is a serious matter at a time when both the Canadian railways are faced with the problem of adjusting rates to greatly increased operating costs; it could only be justified by the C.P.R. having had favourable experience with the more or less experimental running that had previously taken place. Evidently the company is satisfied that in due course considerable economies will result.

Touching once more upon details, the engines are provided with two vapour generators—probably the product of the Chicago offshoot of the Clarkson Company—to heat the passenger cars in winter, each

FIG. 32—TWO-UNIT, 3000 H.P. DIESEL-ELECTRIC LOCOMOTIVE

* I hope the reader will acquit me of inventing this neologism—the C.P.R. is more the culprit. But, after all, the word is graphic and explanatory, and will probably find its way into the dictionary sooner or later.—E.H.L.

capable of converting 250 gallons of water per hour into steam, the tanks carrying 1950 gallons. This quantity almost doubles the steam generating capacity of the earlier diesel passenger locomotives. Their high speed, heavy haulage capacity and inherent reliability reinforce their other merits, and are part and parcel of diesel-electric power—such as ability to take curves faster due to a low centre of gravity, absence of hammer blow, duality of power units, making total failure unlikely, and so on. All this makes for maximum availability which, it is expected, will be coupled with low cost of maintenance; the greatly decreased fuel cost hardly needs stressing. Diesel-electric locomotives undoubtedly have advantages which I should be the last to deny; I am only sorry that so little has ever been done to develop multi-cylinder high-speed dual truck steam locomotives, which might have postponed the end of steam power on railways to a much later date.

So much for the introduction of diesel-electric motive power to the C.P.R.; we now come to the later experimental running that spelt "the end of the era" of the steam locomotive among the mountains of British Columbia, and no doubt in due course will mean its disappearance from the whole Canadian Pacific system. In the latter part of 1949 the electromotive division of General Motors Corporation, La Grange, U.S.A., loaned to the C.P.R. a demonstration three-unit 4500 h.p. diesel-electric locomotive in order that it might be thoroughly tested for several months in both passenger and freight service under winter conditions, both in the rugged territory of Northern Ontario and over the heavy gradients so typical of the Rockies and Selkirks—that is to say, over the actual divisions that the C.P.R. had decided would be among the first to be "dieselised." For six weeks the engine, No. 7001, handled a passenger train from Toronto to Fort William, 711 miles, and back to Chapleau, 380 miles. It then hauled "The Dominion" from Fort William to Vancouver, 1892 miles, and back to Calgary, 642 miles, during some of the worst weather of that exceptionally severe winter 1949–50, during which at Banff, not considered a very cold place, the thermometer plunged to 58 deg. below zero. After that it operated mainly in freight service between Calgary and Revelstoke, with occasional freight trips to Coquitlam—on the main line 16 miles from Vancouver—and passenger runs between Calgary and Winnipeg, 832 miles; the latter stretch, incidentally, is covered by one steam locomotive, a "Royal Hudson," in both directions. Quoting Mr. Leo George, assistant chief of motive power and rolling stock:

"In general, the performance of this locomotive was very satisfactory, and demonstrated to the Canadian Pacific Railway that with some modification diesel-electric power could be operated the year round in Canada's severest weather." Fig. 33 illustrates this engine and the accompanying table gives certain dimensions and other information.

FIG. 33—NO. 7001 WITH DYNAMOMETER CAR

4,500 H.P. Diesel-Electric Locomotive No. 7001

Major dimensions:	
Distance, pulling face of front coupler to centre line of No. 1 truck	10ft 8in
Distance between bolster centres	34ft
Truck, rigid wheel base	9ft
Distance, pulling face front coupler to rear coupler	54ft 8in
Width over body posts	9ft 10in
Width over handholds	10ft 8in
Height, top of rail to top of carlines	14ft 0½in
Overall height, over horns	15ft
Drive:	
Driving motors	Four
Driving wheels	4 pairs
Diameter wheels	40in
Gear ratio	62 : 15
Maximum locomotive speed	65 m.p.h.
Weights and supplies, each unit:	
Total loaded weight on rails (approximate)	258,000 lb
Car body and equipment (approximate)	182,400 lb
Truck, total (two)	75,600 lb
Fuel	1200 gall.
Sand	16 cu ft
Cooling water	230 gall.
Lubricating oil	200 gall.

Truck swing designed for 23 deg. curve or 250ft radius with 2½in free lateral motion in the truck bolster and ¼in in Hyatt journal boxes.

All the General Motors locomotives are fitted with the "567B" engine, the number of cylinders varying according to the power required. The 1500 h.p. "road-switcher" and each unit of the 3000 h.p. locomotive (Fig. 32) or 4500 h.p. three-unit combination (Figs. 33 and 34) are all fitted with sixteen-cylinder engines, while the 2250 h.p. locomotive (Fig. 31) has two twelve-cylinder engines. This 567B engine is two-cycle "V" engine, scavenged by a Rootes blower, the bore being 8½in and stroke 10in. The air inlet ports are in the cylinder walls, with four exhaust valves in the head. The pistons are cast aluminium, oil-cooled, and two connecting-rods drive on each crank. The speed range is from 275 r.p.m. when idling, to 800 r.p.m. at full throttle, and governing is by isochronous hydraulic mechanism.

The C.P.R. now has a large number of freight locomotives, built by the American Locomotive Company, and its subsidiary, the Montreal Locomotive Works. Until recently these units were rated 1500 h.p. but they are now termed 1600 h.p. machines. They are fitted with Alco "244C" and "244D" engines, the principal difference between them being the power output. The engine is a four-cycle V-twelve-cylinder design, 9in bore and 10½in stroke, and is fitted with an exhaust-driven turbo supercharger, two inlet and two exhaust valves being placed in the heads. The compression ratio is 13/1 and the speed range 350/1000 r.p.m.; the governor is isochronous electro-hydraulic.

The company has recently obtained on loan two Fairbanks-Morse 1600 h.p. units, which are being tested in the Rocky Mountains. Each unit is fitted with an eight-cylinder opposed-piston engine, with two crankshafts connected by bevel-geared shafts. Two camshafts operate the fuel pumps and injectors of each cylinder and scavenging is by a Rootes blower. The speed range is 300/850 r.p.m., and governing is as in the other engines mentioned.

Fig. 54 shows the engine at Field—the temperature might have been 20 deg. to 30 deg. below zero when the photograph was taken, and the headlamp was evidently burning, tunnelling through the snow-dust—all very typical of railroading in Canada during the winter. Fig. 35 shows the engine at Vancouver, about to pull out with "The Dominion," in weather far from representative of the coastal city's climate, which is, to say the least, moist in winter. Vancouver's coat-of-arms should include an umbrella *rampant* over a pair of goloshes *couchant* in a field *mud*, or something to that effect—only don't tell any Vancouverite I said so!

This "demonstrator" locomotive, it will be seen, is made up of an "A" unit and two "B" units; the only basic difference between "A" and "B" units is that the former has the cab and controls in it; otherwise, the two units

FIG. 34—NO. 7001 AT FIELD, B.C.

are identical in power and equipment. This particular engine was geared for a maximum speed of 65 m.p.h., all that is necessary over B.C. and Schrieber divisions, at any rate. The gear allows a continuous tractive effort of 40,000 lb per unit, or a total of 120,000 lb, far more than is put out by the 2–10–4 "Selkirks" that No. 7001 was displacing, 89,000 maximum. The "A" unit has a length of 54ft 8in and weighs 110 tons; the "B" units are 50ft and weigh 100 tons. The total length of the three-unit engine is 154ft 8in and the weight 310 tons. The corresponding figures for the "Selkirks" are length 97ft 10in, weight 325 tons. Each unit carries 1200 gallons of fuel oil, and the "A" unit has a 2500 lb steam generator as against each of the "B" unit's 4000 lb.

During these tests No. 7001 ran straight through from Winnipeg to Vancouver, 1473 miles, whereas steam traction calls for three engines, one, a "Royal Hudson," from Winnipeg to Calgary, a "Selkirk" from Calgary to Revelstoke, and another "Hudson" thence to Vancouver. No. 7001 made ten stops for water in that distance, the steam locomotives make thirty-two, and the diesel was refuelled only once—at Field. While working in Northern Ontario the diesel ran on only two units most of the time, but naturally all three were switched on in the mountains.

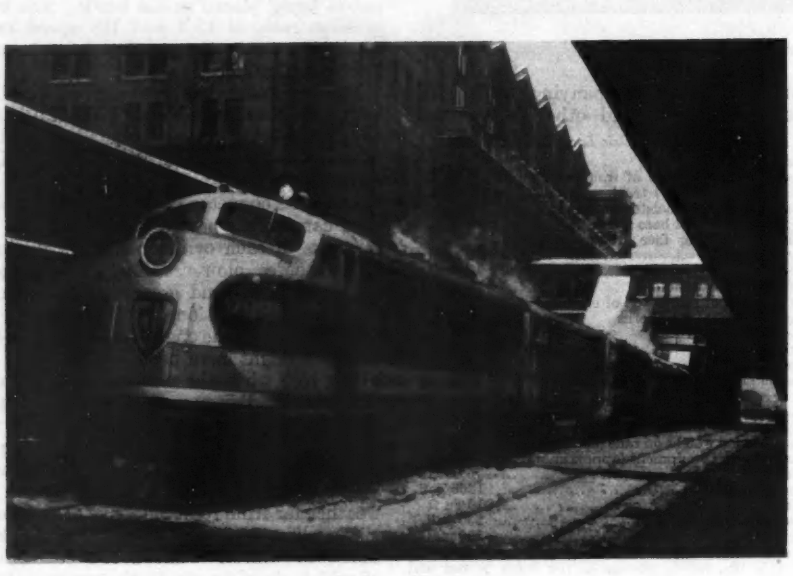


FIG. 35—No. 7001 AT VANCOUVER

The 120,000 lb tractive effort of No. 7001—and of her sisters when there are any—should eliminate a great deal of "pusher" assistance, which is called for frequently at four points between Stephen—the Rocky Mountain "peak"—and Kamloops. Two "pushers," or "pilots" as they would be termed in Britain—they are called pushers in Canada because they pull—were employed more than once on the steam-powered trains dealt with in the earlier parts of this series. This practice caused me some surprise, as I had never previously observed more than one being used on passenger trains. I cannot say whether No. 7001 could handle a 1300-ton train single-handed right through the mountains, but, if so, the entire elimination of all pusher assistance should go far to offset the greater cost of construction of the diesel engines. This cost is, of course, much greater; I won't give figures because I discover I am not quite sure of them, and might unwittingly exaggerate; but I can assure the reader they are vastly greater. In comparison with the relative simplicity even of a big 2–10–4 "Selkirk" the complexity of a three-unit diesel-electric locomotive is fearsome; forty-eight cylinders three generators, twelve traction motors, three steam generators, plus all the associated connecting and controlling gear, automatic and semi-automatic, to say nothing of the more delicate and intricate running, braking and suspension gear. I do not know whether a three-unit diesel-electric engine operating in Canada calls for a "maintainer" in addition to the usual driver and fireman, but a maintainer (fitter or mechanic) was pursuing his vocation on the twin-unit "400" I rode between Chicago and Minneapolis a few years ago, as was described in THE ENGINEER at the time. That, however, would only mean three enginemen; a "Selkirk" and two pushers call for six.

Manual controls are very similar to those of the steam locomotives with which the enginemen have been familiar; so say the General Motors people, but personally I think this should read "very similar *in number and purpose*"—in appearance and movement they are totally different. As well pretend similarity between the controller of a tram and the regulator and reverse gear of an ex-L.N.E.R. "A4"! The controls consist chiefly of a throttle, reverse lever, and locomotive and train air brake levers. The engineer (*Anglice*, driver) and fireman sit in upholstered swivel chairs designed for comfort when occupied for long periods, and all the controls have been placed where they can be reached with the easiest and most natural movements of arms and body. The operation of a diesel locomotive calls for much the same major motions as a steam engine, so far as throttle, reverse and brakes are concerned. One must not run this "similarity" business into the ground! The driver's position gives him an unobstructed view ahead, and also covers approaching road vehicles over a wide arc on either side, the window in front extending the full width of the cab and being kept clear in all weathers by a windscreen wiper and automatic defroster, and sun visors go far to prevent dazzle. The cab is heated by hot water in winter and kept cool in summer by roll-down side windows. Track and engine noises are absorbed by sound-proofing material in the ceiling, and the enginemen can talk across the cab without raising their voices above the ordinary conversational tone. I have no doubt this is so—it was in the cab of the "400" I rode out of Chicago—it was not so in the cab of No. 6200, 4–8–4 steam locomotive, on the "Intercity Ltd.," between Toronto and Montreal recently, when a raucous bellow often produced nothing but a request to repeat a remark, and even that sometimes failed to register above the thunderous, roaring turmoil. While there are similarities between steam and diesel controls, there are also differences. When the engineer "pulls the throttle" automatic devices result in the engine generators and traction motors in combination doing what is necessary according to the throttle position. If there is slipping, a white light flashes on the instrument panel in front of the driver, and the load is automatically taken off the generator. If lubricating oil gets low or an engine overheats, a gong sounds and a warning light flashes. Driving a diesel-electric is very much simpler than handling a steam locomotive; in fact, General Motors claim, no doubt with truth, that steam engineers graduate to the diesel locomotive after only one or two trips with an instructor. As to the fireman, at most times he is more ornamental than useful, except as a look-out, but union rules ordain that he must be on the job—even if he is asleep! The unions tried to get a fireman on every unit, but failed; had they succeeded no doubt the next step would have been to have an engineer too to keep him company; this may yet come.

Speaking of "dieselisation" in his year-end review, Mr. W. A. Mather, the president of the C.P.R., can be quoted as follows:—"It continues to be disappointing, however, that, with buoyant traffic conditions, the ratio of net earnings to gross earnings remains at the lowest level in the company's history. Faced with this situation, the C.P.R. has had to continue to practise the strictest economy in its operations in order to meet its immediate financial obligations. While our equipment is not all we would desire, because of inadequate financial returns and the high cost of replacements, we have embarked on an extensive programme of dieselisation which it is expected will produce substantial savings in transportation costs, although the amount necessary to purchase this new equipment represents a heavy outlay which could not be justified except in terms of those savings."

I omitted to mention "switchers"—yard engines—requiring refuelling only once every three days and routine inspection once a month compared with the daily attention and replenishment the steam locomotive demands, and performance charts show they have consistently done eight hours' work on 30 gallons of fuel oil. They are now to be seen working in all the major yards across Canada, and in minor ones, too—such as Esquimalt/Victoria. In conclusion, the great oil discoveries in Alberta and Saskatchewan have provided a vast new source of fuel not only for the diesel engines but for the steam locomotives, too; more than a hundred "Hudsons" and freight engines and all main line passenger power operating between Winnipeg and Vancouver now use liquid fuel. It is indeed the end of an era—of steam locomotives and of coal as a source of power. The future is with oil.

FOUNDRY INFORMATION LEAFLETS.—Information sheets giving helpful hints on a wide variety of foundry topics are published by Foundry Services, Ltd., of Long Acre, Nechells, Birmingham, 7. The three latest sheets issued by this firm, which have just been issued, deal with high tensile brass alloys, nodular cast iron and malleable cast iron. These sheets, which are issued free of charge to interested firms, contain much valuable, up-to-date information on their subjects and incorporate notes on the use of the company's products in relevant foundry practice.

Hydro-Electric Power in the Isere Catchment of the French Alps

No. V—THE UPPER ISERE

(Continued from page 756, December 14th)

AN ambitious programme of works is at present in progress in the upper part of the Isere, where Electricité de France has formulated proposals which will utilise substantially all of the extensive resources which are available in that part of the catchment. There are a number of hydro-electric power stations on the upper Isere and its tributaries which have been in existence for a number of years, and which in some cases owe their existence to the electro-chemical industry, but their production of power is only a small fraction of that which will result from the present series of projects.

A glance at the accompanying illustration, Fig. 29, will give an idea of the extent of the works which are proposed or are in course of construction. To the south-west is the River Arc, which was one of the tributaries dealt with in Part III of this article; to the north is the Arly and the Doron de Beaufort, which were the subject of Part IV in our issue last week, and the projects shown diagrammatically in Fig. 22 may be observed. It will be seen, however, that the proposed diversion works centred on the storage reservoir of Roselend, which was also mentioned last week, involve a tunnel leading to a power station at La Bathie, on the Isere itself; this power station will be a large one, with an installed capacity of 320MW, and will operate under a gross head of 1200m, which is about the same as the highest existing head of the Alpine schemes at Bissorte. The major development at Aiguebelle (Randens power station) involves diversion works and a tunnel which will divert the flow of the Isere into the Arc, utilising the difference in level which exists between the two rivers at this point. Since the headwaters of the various streams in this area are largely fed by glaciers, the maximum flows occur in spring and summer. (Some typical figures were given in Part I of this article for the flow at Tignes.) Seasonal storage is therefore of crucial importance, and the development policy has been based on the need for large storage reservoirs. The present position is that the natural storage provided by the lake of La Girotte has been augmented to give a reservoir with a capacity of about 40,000 acre-feet, as mentioned last week, and preliminary work on the Roselend reservoir has been started. The Roselend dam will have a storage capacity of the order of 245 million cubic metres (about 200,000 acre-feet). These two reservoirs were illustrated in Fig. 22 of Part IV. On the Isere itself the most favourable reservoir site is at Tignes, where work is at present in progress. The reservoir will have a capacity of 190,000 acre-feet. There are one or two reservoir sites above Tignes, principally that at Prariond (capacity 20,000 acre-feet), which are at present under survey. The site of another major storage reservoir is under survey on the Doron de Champagny, where it is hoped to create a reservoir with a capacity of about 167,000 acre-feet, as mentioned below. The developments under discussion here were influenced by the decisions taken on the proposed Mont Cenis reservoir (proposed capacity about 200,000 acre-feet), which was mentioned in Part III, since the diversion of some streams into either the Tignes or Mont Cenis reservoirs was being considered. The arrangement shown in Fig. 29 was arrived at after the decision to abandon the Mont Cenis scheme was taken.

The three principal reservoirs which are still under survey or construction—Tignes, Roselend and Champagny—will provide a storage of some 550,000 acre-feet at high altitudes if all three are built as at present envisaged.

The importance of these three large reservoirs may be illustrated by comparison with earlier attempts at regulating the flow in the various streams of the Isere basin. The use of the lake of La Girotte dates back to the beginning of this century, as was described in Part IV. The first storage dam was built at Chambon (River Romanche) about twenty years ago to give a storage capacity of about 40,000 acre-feet, the annual flow of the river being about 210,000 acre-feet. Le Sautet dam on the Drac has a storage capacity of some 80,000 acre-feet, with a river flow of the order of ten times as great. It was only at Bissorte, the most recent of the three, which utilises a tributary of the Arc, that complete control of the river flow was achieved.

Pralognan Power Station

The Doron de Bozel, the tributary south of Moutiers, has been developed for more than thirty years as far upstream as Pralognan (Fig. 29). Recently, however, the power station of Pralognan has been built to utilise the waters of the Doron de Pralognan. Both the Doron de Pralognan and the Doron de Champagny have a substantial flow in the summer months when the Alpine snow and ice is melting. It is intended to construct a large seasonal reservoir on the Doron de Champagny, and the diversion of the Doron de Pralognan was arranged so that it will be possible to divert water into that reservoir when necessary. Accordingly, the intake works were sited at a sufficiently high level (1642 N.G.F.), which necessitated the construction of a long diversion runnel, 12·75km long from the intake to the surge chamber, the latter being positioned midway between the two streams to facilitate the proposed connection with the Champagny reservoir. Various side streams are connected to the tunnel,

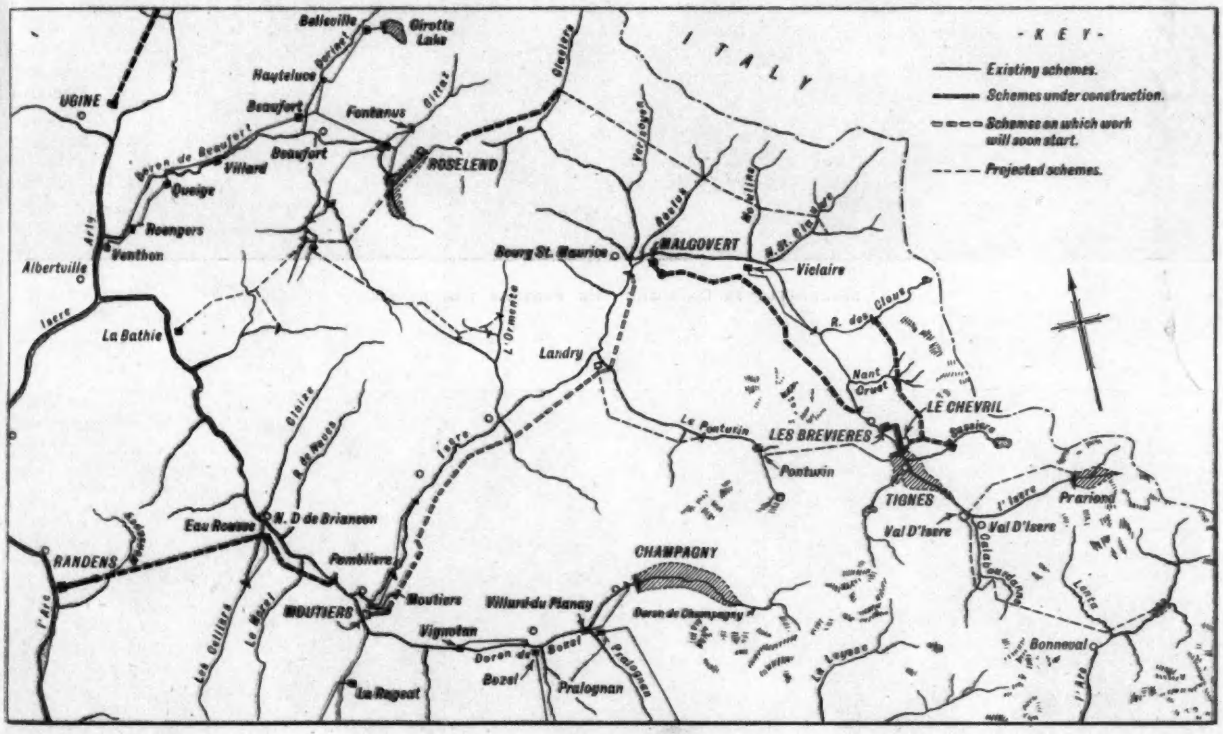


FIG. 29—THE UPPER ISERE

PROGRESS OF THE ARCH DAM AT TIGNES ON THE UPPER ISERE

FIG. 30—TIGNES DAM AND THE PLATEAU DES BOISSES

FIG. 31—TIGNES DAM FROM DOWNSTREAM

each involving intake works with careful provision for the exclusion of sand and silt from the diverted water. The work was carried out under very difficult conditions, and included a siphon crossing of a ravine and tunnelling through water-bearing strata with the aid of injections of cement grout in one length of the work. The capacity of the tunnel is 10 cubic metres per second, the flow required in the power station being 8 cubic metres per second.

The gross head of the scheme is about 725m, so that the design of the penstock, which is 1705m in length, is of some interest. Its diameter varies from 1·45m to 1·30m, and according to the internal pressure various techniques of construction have been adopted. At the top it is a single welded steel pipe, whilst lower down auto-frettage has been employed. French practice in the design of high-pressure penstocks is mentioned later on in this article in connection with the Malgovert power station.

The power station of Pralognan was completed in 1949. It contains three 17MW horizontal turbo-alternator sets, each consisting of an alternator, generating at 10·5kV and 750 r.p.m., driven by two Pelton wheels. There are two transformers of 28MVA, raising the voltage to 150kV for transmission, which are situated inside the power station owing to the proximity of an electro-chemical factory, the fumes from which would otherwise have caused difficulty. The annual power production is at present about 170 million kWh, principally in the summer months. A development not shown on Fig. 29, and extending from the tail-race of Pralognan, utilising the Doron de Bozel as far as Moutiers, where a third power station would be built, in addition to the two taking water from the Isere itself, is at present being investigated.

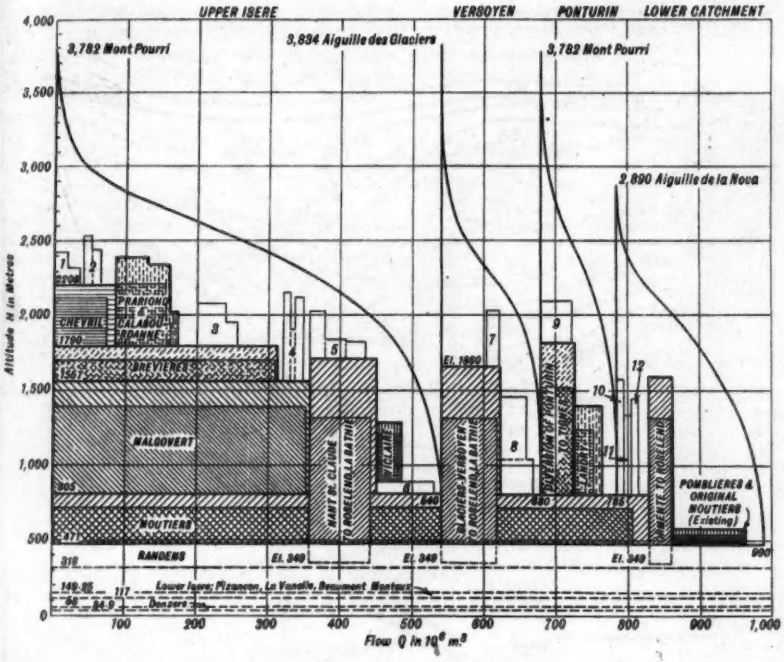


FIG. 32—POWER POTENTIALITIES OF THE UPPER ISERE

Actual Production and Installed Capacities

	Net annual production, kWh × 10⁶			Installed capacity, MVA
	Isere catchment	Diversion from River Arc	Total	
(A) Power stations existing or under construction :				
Chevril	65	—	65	25
Brevieres (with diversion of Ponturin)	138	45	183	108
Malgovert (with diversion of Ponturin)	628	175	803	320
Viclaire (after completion of Malgovert)	28	—	28	20
Pomblières and original Moutiers (existing) (after completion of projected Moutiers)	16	—	16	17
Total	875	220	1095	490
(B) Projected schemes :				
Moutiers (without flows to be diverted to Roselend)	430	70	500	160
Nant St. Claude, Versoyen and Ormente (to Roselend and La Bathie)	450	—	450	La Bathie
Prariond and Calabourdanne (Val d'Isere)	85	50	135	30
Landry (Lower Ponturin)	40	—	40	18
Total	1005	120	1125	208
(C) Projects of over 5×10^6 kWh which appear possible *a priori* :				
(1) Lac de la Sassiere and Saut	10	—	—	3
(2) Nant Cruet and Upper Clous	12	—	—	4
(3) Sachette and Lac de Tignes	24	—	—	15
(4) Left bank tributaries of Isere, above level of Malgovert intake	27	—	—	12
(5) Right bank tributaries of the Isere, above the level of the Roselend intake	26	—	—	12
(6) Isere downstream of Viclaire	11	—	—	4
(7) Upper Versoyen	10	—	—	4
(8) Lower Versoyen	35	—	—	12
(9) Upper Ponturin	20	—	—	6
(10) Charbonnel	10	—	—	4
(11) Arbonne	7	—	—	3
(12) Bonnegarde	8	—	—	3
Total	200	—	—	82
Grand total	2080	340	2420	780

DEVELOPMENT OF THE UPPER ISERE

Reference to Fig. 29 shows that there is a group of three major projects on which work has at present started on the Isere above its confluence with the Doron de Bozel at Moutiers. At Tignes a large arch dam is being built, to provide a major storage reservoir, and the power station of Les Brevieres is immediately downstream of the dam. The forebay of the Malgovert tunnel is a short distance downstream of Les Brevieres leading to the main power station of the group. Construction of these projects is well advanced. Preliminary work only has been carried out on the next scheme —a forebay just downstream of Malgovert and a diversion tunnel leading to a power station at Moutiers.

The relative importance of these three developments is well exemplified in Fig. 32.

Actual and Theoretical Production of the Isere Upstream of its Confluence with the Doron de Bozel (471 N.G F.)

	Total theoretical production, in millions of kWh	
	Gross $9 \cdot 81 f Qdh$	Net $7 f Qdh$
Upper Isere, to level 805	2420	1730
Versoyen	540	385
Ponturin	490	350
Lower catchment, to level 471 :		
Main flow (between 805 and 471)	735	525
Flow from source level to 471	715	510
	4900	3500

Percentage Utilisation

Theoretical net possibility = 3500×10^6 kWh = 100 per cent

	Per cent
(A) Power stations existing or under construction	25·0
(B) Projected schemes	28·7
(C) Projects of over 5×10^6 kWh which appear possible *a priori*	5·7
Total	59·4

Production per square metre of catchment = 2·3 kWh.

In this illustration, the altitude and flow of the river form the ordinates and abscissæ respectively, the area under the curve corresponding to the power which is theoretically available. The gross power of Les Brevieres, Malgovert and Moutiers is shown by the three large rectangles enclosed by the heavy lines on the left-hand side of the graph; the rectangles enclosed by the lighter lines give the net power, the difference between the two being due to the overall operating efficiency of the machines and hydraulic works (loss of head) and to the spillway losses (loss of flow). The three principal groups of tributaries in this part of the river are shown separately. The curves of river flow are obtained from a study of curves of catchment area against altitude and of annual run off against altitude. The various developments shown may be identified on Fig. 29, where it will be seen which of them correspond to future projects and which to works now under construction. The dotted part of the graph below the elevation of 471 gives an indication of the power utilisation further downstream—Pizançon, La Vanelle and Beamont-Monteux were described in Part I and the Donzere power station, on the

Rhone, below the confluence with the Isere, was described in THE ENGINEER last December. It may be noted that the production of the two existing power stations at Pomblieres and Moutiers and one at Viclaire is at present much larger than that indicated on the graph, which shows the production at these two power stations after the other schemes are in operation. Further details of the various developments are given in the accompanying table, which should be read in conjunction with the illustrations. It may be noted that the figure of production per square metre of the catchment is quite high at 2·3kWh. By comparison, the figure for the river Po in Italy, also an Alpine river with a mountainous catchment very favourable for hydro-electric development, is about 3·0kWh per square metre.

TIGNES DAM

After these consideration of the hydro-electric possibilities of the Upper Isere, it will perhaps be of interest to turn to an account of some of the work which is at present in progress. The provision of storage at as high an altitude as possible was one of the earliest requirements of the development programme, and an unusually favourable site for a storage reservoir was known to be that at Tignes, where an arch dam 590ft high is under construction. The useful capacity of the reservoir which it will form will be about 187,000 acre-feet. The top water level is 1790 N.G.F. and the storage is equivalent to 700 million kilowatt-hours of electrical energy, when considered to flow through the series of power stations downstream, as far as Donzere on the River Rhone. The energy equivalent of all the existing storage reservoirs in French hydro-electric schemes is about 1600 million kilowatt-hours, so the importance of the Tignes reservoir, which adds about 44 per cent to the total, may well be appreciated.

Tignes dam was designed by the method developed by Monsieur Coyne, involving analysis of a thin inclined arch section of the dam. A description of this analysis has been given elsewhere.* The accompanying sketch Fig. 34 gives the particulars of the cross-section of the dam as defined by this method and also shows a cross-section at the axis of the dam. Fig. 33 shows the dam in plan.

During construction the Isere has been diverted into a tunnel driven through the right bank at a level of 1630 N.G.F. Vertically above it a second tunnel has been driven to accommodate a temporary diversion of the highway R.N. 202, until such time as the reservoir is filled. A new highway at the high level has recently been brought into use. Both tunnels will be plugged on completion of the work. The dam will incorporate an intake for the Brevieres power station and two scour culverts. The screens and controls for these openings are grouped together on the upstream side of the dam, with the exception of the needle valves for the scour pipes, as shown in the cross-section. These intake works may be seen under construction in Fig. 35, whilst Figs. 30 and 31 give a good idea of the dam and reservoir site, and of the progress of the work.

The dam is founded on hard quartzite, the quality of the rock being very good and the covering of top soil and broken rock at the site being small. Thus only 90,000 cubic metres of excavation has been necessary, a small quantity considering the size of the finished structure. The quartzite formations dip in the downstream direction so that whilst they ensure a high degree of impermeability in the reservoir generally, pressure grouting has been necessary along the footing of the dam to prevent any leakage along the line of dip, but not to a very great extent.

A point of particular interest is the design of the concrete mix. At the high elevation of the Tignes dam the winter conditions are severe and the concrete must consequently have a high resistance to frost. This problem was particularly acute in the case of La Girotte dam and a concrete laboratory was established on the site to study the problem. That laboratory has now been transferred to Tignes, where its work is continuing. The results which it has achieved have recently been described by Monsieur Combe.† Concrete test pieces were submitted to cycles of freezing at −25 deg. Cent. and thawing at +20 deg. Cent., each cycle lasting one day. They were then tested for compressive and bending strengths, for impermeability and for resilience to impact. As a result of this work it was considered that cement should be chosen from freezing resistance tests; fine dust should be removed altogether from concrete aggregates; the water-cement ratio should be as low as possible; and there is a correct maximum quantity of cement, which it is useless to exceed. It was also found that resistance to cold depends on the length of time that the concrete has been allowed to harden before freezing, and that the use of additional substances, such as air-entraining agents, may improve certain concretes, but did not appear to be essential.

In practice, the concrete of the Tignes dam has been proportioned with 200kg of cement per cubic metre with discontinuous grading of the aggregates, there being 22·5 per cent of 0·2mm to 3mm, 32·5 per cent of 50mm to 135mm, and 45 per cent of 120mm to 250mm. The aggregate is a hard limestone and Portland low-heat cement is employed with a heat of hydration which must not exceed 80 calories per gramme at twenty-eight days; an air-entraining agent is added to give 5 per cent of air entrainment. This concrete gives compressive strengths of 380kg per square centimetre at ninety days and 285kg after fifty freezing cycles after twenty-eight days.

CONSTRUCTIONAL PLANT

The constructional schedule of the Tignes dam envisaged the placing of the great majority of the 650,000 cubic metres of concrete required in three summer seasons in 1950, 1951 and 1952. Owing to the high altitude concreting can only be carried out for about 150 days in the year, so that a rate of concreting of about 180 cubic metres per hour was decided upon. Two concrete plants have been installed, the second of which was intended for concreting the lower part of the dam in the early stages of construction,

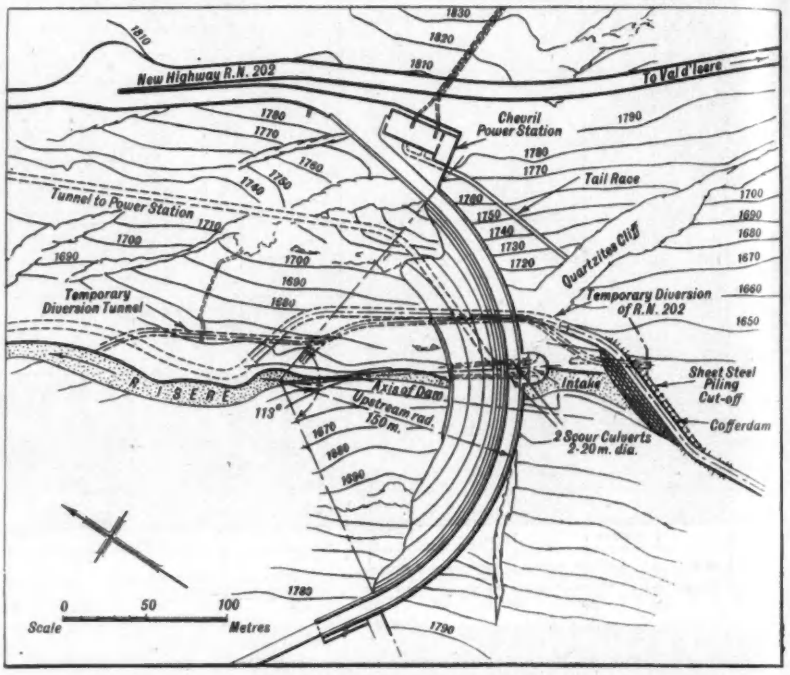


FIG. 33—PLAN OF TIGNES DAM

and then for supplying concrete to other works such as the power station, tunnel and penstock and other ancillary works. The main concreting plant is installed on the Plateau des Boisses, a convenient area of comparatively flat ground at a high level on the left bank of the dam site; the plant installed there can be clearly seen in Fig. 30. This plant is an elaborate installation of large capacity which is intended to facilitate close control of the quality of the concrete and ensure freedom from interruptions in the concreting due to breakdowns. Each section has therefore been duplicated, with the exception of the primary crusher and the concrete batching and mixing station, the two halves working independently so that work can still proceed in the event of a breakdown. To give further reliability, ample stocks of the various materials have been allowed for. The entire plant can be dismantled for use at another site when the Tignes dam is completed.

Cement is brought in bulk to the railhead at Bourg Saint Maurice, where six storage silos, each of 6000 tonnes capacity, have been built. It is then transported by a monocable ropeway of 30 tonnes per hour capacity leading along the valley to the four 600 tonnes silos adjacent to the concrete batching plant. The monocable is 21km in length and also supplies the adits of the Malgovert tunnel. The cement is handled in bulk by compressed air equipment from the silos to the concrete batching plant. To ensure continuity in the

* "Modern Trends in Arch Dam Construction and Design," by O. Jaeger, *Civil Engineering*, May, 1950; and "Leçons sur les Grands Barrages," by A. Coyne, Ecole Nationale des Ponts at Chaussées, 1943.

† Fourth Congress on Large Dams. Question No. 15, paper, R52, "Etudes sur le Gel du Béton."

supply of cement an arrangement was made so that one kiln of the cement works of the Usine Lafarge du Teil, with a monthly production of 5000 tonnes, was set aside solely to supply the project, and the large storage capacity at Bourg Saint Maurice was necessary to build up a stock in the winter months. With concreting in full swing, about 10,000 tonnes of cement is used in a month. Constant quality control of the cement is ensured by taking samples for testing from each batch of 600 tonnes.

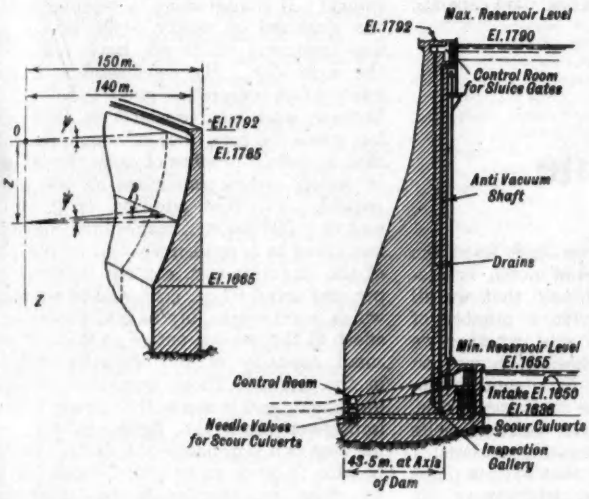
Aggregate is obtained from a limestone quarry some 2km upstream from the dam. Primary crushing is carried out at the quarry, where 2500 tonnes of crushed aggregate can be stored. It is transported to the dam site by two bicable ropeways, each of 200 tonnes per hour capacity, discharging over a set of hoppers on the plateau of Les Boisses. Belt conveyors pass under these hoppers, and convey the aggregate to the secondary crusher house, where it is crushed and graded into five sizes, 0mm to 3mm, 3mm to 15mm, 15mm to 50mm and 120mm to 150mm. This plant includes compressed air dust extraction, which ensures that all the "flour" below about 0·3mm in size is removed. Belt conveyors then take each size of the graded aggregate to a covered storage area of 20,000 tonnes total capacity, from which further belt conveyors lead to the batching plant.

The concrete batching and mixing tower has been built according to the latest practice, weighing of the aggregates, water and cement being effected automatically and controlled from a central panel. The humidity of the fine aggregate is compensated; there are six aggregate bins grouped round a central cement bin above the weigh-batching plant, which discharges into four 3 cubic yard (2·3 cubic metres) concrete mixers. The mixers discharge in pairs into skips of 6 cubic metres capacity, or into 3 cubic metre skips. The concrete is mixed for a minute and the skips are transported on trucks, hauled by diesel locomotives to the cableways. There are three cableways, two of 20 tonnes capacity, which take the 6 cubic metre skips, and one of 10 tonnes, which takes the smaller skips. The tailmasts of the cableways run on rail tracks so that they can cover any area of the dam as required.

The secondary concrete station is situated just downstream of the dam site at the lower level and is supplied with cement directly from the main silos, and with aggregate by road. It has two 1500 litre concrete mixers. For concreting the lower part of the dam, skips were taken from the mixer to two tower cranes by diesel locomotives. The cranes ran on temporary reinforced concrete gantries, one on each side of the dam.

The concrete is placed inside metallic shutters giving a lift of 1·5m, in blocks, each running the full width of the dam and about 12m along its length. Copper sealing strips are provided between the blocks near the upstream face with various supplementary steel strips nearer the downstream face; the vertical joints are also grouted, pipes being left in them for that purpose. The usual precautions necessary for efficient curing and for the treatment of construction joints between lifts are carried out rigorously to ensure work of the highest quality, but special cooling arrangements have not been necessary.

During the summer concreting season of this year an average rate of concreting of 2500 cubic metres each twenty-four hours was maintained, and the greatest output achieved in a twenty-four-hour period was 3300 cubic metres.



Surfaces of Dam

Upstream face: vertical cylinder of 150m radius.

Downstream face:

(1) Below level 1665, vertical cylinder defined by the polar equation

$$\rho = 140 - 98 \cdot 743(1 - 0 \cdot 66 \cos \phi) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

(2) Between levels 1665 and 1785, polar equation of surface is

$$\rho = 140 - z^2(360 - z)\left\{\frac{1 - 0 \cdot 66 \cos \phi}{35{,}000}\right\} \quad . \quad . \quad . \quad . \quad (2)$$

With z constant, equation (2) gives a horizontal curve of the downstream face. With ϕ constant, it gives, on a radial cross section, a vertical curve of the downstream face.

At the level 1785, the curve is a circle with $\rho = 140$.

(3) Above level 1785, vertical cylinder, radius 140m, with a transition to the crown.

FIG. 34—TIGNES DAM

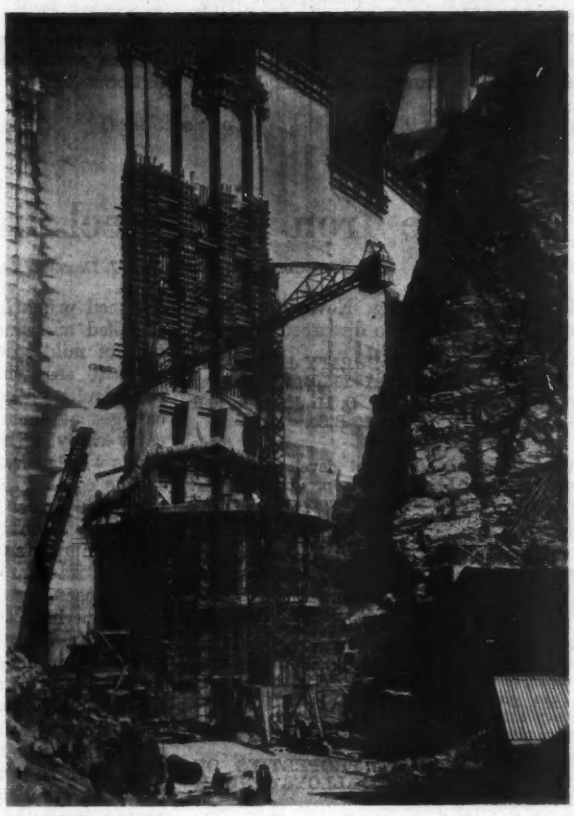


FIG. 35—INTAKE STRUCTURE—TIGNES DAM

LES BREVIERES POWER STATION

The intake from Tignes dam, which is at a level of 1650 N.G.F., as shown in Fig. 34, leads to a steel-lined diversion tunnel, capable of withstanding the head of 490ft due to the reservoir. The tunnel is driven under the right bank of the Isere for a length of about 920m; it is circular in cross-section with a radius of 3·75m. There is a valve house at its downstream end and then a penstock, 207m long and 3·2m in diameter, leading to Les Brevieres power station, in which there are three Francis turbine sets, each of 31MW capacity. The turbines discharge into an open channel which rejoins the Isere 4000ft upstream of the forebay of the Malgovert tunnel; the channel is 8m wide with masonry walls and the Isere itself will be deepened and improved between Les Brevieres and the Malgovert forebay.

The average annual production of power at Les Brevieres will be about 180 million kilowatt-hours, and the turbines will operate under a gross head varying between 232·5m and 92·5m (mean gross head 190m). Two pumps, each of 9000 h.p. (equivalent to a capacity of 2400 litres per second) will be installed in the power station.

The alluvial deposits at the power station site were somewhat varied in their nature and did not provide a good foundation. It was therefore decided to found the machine room directly on the bedrock, with a joint between it and the other buildings, where the rock dips away from the surface. In the latter case the foundations were constructed by sinking pits down to the rock at intervals, filling them with concrete and then connecting them by a reinforced concrete slab.

The three turbines are each equipped with a relief valve and the usual governing and auxiliaries, with a Pelton-wheel-driven emergency governor oil pump. They will be solidly coupled to the air-cooled alternators, which will run at a normal speed of 375 r.p.m. for a frequency of 50c/s and a continuous power output of 36MVA at 0·86 power factor. The

nominal generated voltage will be 10·3kV±5 per cent, regulated under load to ±10 per cent. The main exciter of each alternator will be of 87·5kW, 106V, and the pilot exciter 6·9kW at 115V. The voltage of the current will be raised to 150kV for transmission by a 31MW transformer for each of the main sets.

Le Chevril and Prariond

Before proceeding to a description of the Malgovert tunnel and power station the proposed developments upstream of Tignes may be noted. These developments were shown in Figs. 29 and 30; some of the details of their lay-out and installed capacities are still under investigation, but constructional work on the first of them has been started. The power station of Chevril will utilise three right bank tributaries of the Isere, with a reservoir formed by a small rockfill dam at the Lac de la Sassiere, and a reservoir of 100,000 cubic metres capacity for weekly storage at the intake of the R. des Clous. It is not at present envisaged that seasonal storage will be provided for this project. The power station, which will be situated on the rocks facing the right abutment of Tignes dam, will contain two horizontal Pelton wheel turbo-alternator sets, with a total installed capacity of some 20MW and producing some 65 million kilowatt-hours annually. The gross head will be 400m and the open channel tail-race will discharge directly into Tignes reservoir, over a "ski-jump" to avoid scouring when the reservoir level is low.

As mentioned earlier, a seasonal storage reservoir is envisaged at Prariond at the head of the Isere. It will be built in conjunction with a power station in the Val d'Isere—the next open valley above the Tignes reservoir site and above which is the Col Iseran, where a highway passes over the mountains at an elevation of 2770m to the Arc valley. The Val d'Isere power station will also be supplied by a diversion of the headwaters of the Arc—the alternative which was decided upon when the Mont Cenis scheme was dropped. About 135 million kilowatt-hours will be generated annually at this power station, which will have an installed capacity of about 30MW.

(*To be continued*)

The Iron and Steel Institute

No. IV—(*Concluded from page 771, December 14th*)

ON Thursday morning, November 22nd the first papers to be discussed were:

PRODUCTION OF HIGH-PURITY IRON AND IRON ALLOYS ON A 25 LB SCALE

By B. E. Hopkins, M.Sc., G. C. H. Jenkins, and H. E. N. Stone, B.Sc.

Synopsis

The method and equipment developed in the National Physical Laboratory to produce iron and iron alloys of high purity as 25lb ingots are described. Starting with a selected batch of Swedish iron, the purification procedure is carried out on the iron in the molten condition in two main stages: (*a*) oxidation of a number of impurities and removal of the products of oxidation; and (*b*) a vacuum treatment for degassing, followed by reduction of oxygen to a low level by dried hydrogen. The experience gained in operating the process over a period of time is recorded. Chemical analyses of the iron before treatment, of the oxidised iron, and of the reduced iron, are given. Some investigation has been necessary into methods of analysis and notes on these are given in an Appendix.

TENSILE AND IMPACT PROPERTIES OF IRON AND SOME IRON ALLOYS OF HIGH PURITY

By W. P. Rees, M.Sc., B. E. Hopkins, M.Sc., and H. R. Tipler, B.Met.

Synopsis

The tensile and impact properties of high-purity iron and of iron-manganese, iron-carbon and iron-carbon-manganese alloys at various temperatures covering the tough to brittle transition are discussed. The technique used to carry out tests at low temperatures is described. Attention is drawn to the two kinds of brittleness, intergranular and cleavage, that can occur in iron. The evidence presented indicates that oxygen is effective in promoting intergranular brittleness. The oxygen content below which intergranular brittleness is not encountered is less when the iron is made in one furnace than in another. The incidence of intergranular brittleness is also affected either by grain size or by some other factor resulting from the treatment used to obtain coarse grains, i.e., straining and heating below the transformation temperature. Manganese and carbon plus manganese are shown to lower the temperature of transition from tough to brittle fracture, and to raise the cleavage strength. The effect of carbon in raising the transition temperature may possibly be explained by the rise in yield stress.

Dr. M. L. Becker (British Iron and Steel Research Association) first commented upon and criticised in some respects the equipment described in the first paper. He then went on to say: The second paper gives the first fruits of the main investigation, designed primarily to throw light upon the so-called and much-talked-of notch brittleness of mild steel. I suppose that we all want to see, when we have a number of test results given in this way, whether we can get at some conclusion which we can carry away with us and have some hypothesis which may be of use to us in practice. In the case of the pure iron series of melts of which figures are given, the authors, I think, have shown clearly that oxygen plays a very important role in determining the type of fracture either in the tensile or in the impact test. As I understand their views—perhaps they have not been quite so definite in the conclusions as they can be now—the presence of oxygen in excess of 0·002 per cent or 0·003 per cent renders the iron liable to show intergranular, as distinct from cleavage, fracture when broken below the transition temperature, 196 deg. Cent. in these tests. From these results and from the transition curves themselves, one cannot resist the conclusion that oxygen—probably present as thin boundary films of FeO, though we do not know—is in some way bound up with the transition temperature itself, even when the content is below that required to promote an obvious intergranular brittle fracture. Looking at the other series of tests in the paper, there seems to be nothing in the tests on the manganese or the manganese-carbon series which would contradict such an assumption. It might be arguable here and there, but I shall not go into the details. On the other hand the carbon alone, in the series of which three alloys were made, should and did reduce the oxygen content and it actually raised the transition temperature. Presumably no intergranular fractures were visible in these tests carried out below the transition temperature as the oxygen content had been reduced to too low a value, so that there was no confirmation from the actual appearance of the fracture. Perhaps the authors would like to confirm that.

It seems to me, however, that it is at least possible that in the carbon series of alloys grain boundary carbide takes the place of grain boundary oxide, which I have just mentioned, in raising the transition temperature. Some confirmation of this hypothesis might be obtained by studying the transition characteristics of, say, the 0·05 per cent carbon alloy treated with a small quantity of a carbide stabiliser such as titanium. This would preclude the presence of boundary carbide films in the normalised material and, if the transition temperature in such material was lowered, I think that the point would have been proved. Another experiment, which no doubt has suggested itself to the authors, would be to treat an iron containing over the 0·03 per cent of oxygen with a small quantity of a powerful deoxidant. Would such an alloy show a lower transition temperature than that appropriate to its oxygen content or would the transition temperature be raised, as when the deoxidation was carried out by carbon? These are points which will no doubt be brought out in later work.

Dr. N. P. Allen (National Physical Laboratory): It is interesting to consider whether the standard of purity (0·01 per cent of any impurity) which we have achieved is the right one. My conclusion is that we have in fact been rather lucky in this matter, because work not reported in this paper, but which has been done subsequently, shows that in quite a number of cases the influence of certain minor impurities on the iron is critical. The first addition of 0·001 per cent or 0·002 per cent makes little difference, but there is a sudden change in the effect of the impurity at a content between 0·01 per cent and 0·02 per cent, and at a quantity which could reasonably be interpreted as the effect of the coming out of solution of some small quantity of the impurity dissolved in the ferrite. Those quantities are quite important, and it seems that in a number of important cases the figure of 0·01–0·02 per cent is a significant one, and we want to be able to go down to about 0·001 per cent in order to disentangle the phenomena properly. In due course we shall want to go below 0·01 per cent to settle certain difficulties and questions that arise, but I am certain that there is a great deal of enormously useful work which can be done on the scale of purity which we have now adopted. The importance of these small amounts of impurities is very great indeed, and, to illustrate their importance, I want to draw your attention to some facts which we have recently realised. You may know that there has been a great deal of thought among engineers along the lines that if the yield-point of structural steel could be raised, then it would be possible to save a great deal of steel in practice by reducing the sections of various girders and so on. There have been developed in recent years high-yield steels which are alloyed in various ways to produce a yield-point which is higher than that of an ordinary steel. There is a specification, B.S. 968, which deals with steel of raised yield-point, and that requires a yield-point of 23 tons per square inch. The yield-point of pure iron such as we have been dealing with is about 5 or 6 tons per square inch, and you may be interested to know what is the minimum alteration of purity of that iron which is necessary to achieve a yield-point of 23 tons per square inch. The answer is that if we add 0·04 per cent of carbon and nothing else whatever and get that carbon into the right structural condition, we can have a material which has a yield-point far above 23 tons per square inch.

B.S. 968 allows for 1·8 per cent manganese and 1·0 per cent chromium, with the condition that manganese+chromium shall

not be more than 2 per cent. You can also have 0·5 per cent nickel and 0·5 per cent copper, and some steels of this class contain 0·1 per cent or 0·2 per cent of molybdenum as well. What are all these alloying elements doing? As far as I can see, they are getting the carbon into the right condition, but nobody knows which of them is effective. Our view is that almost the whole alloying element is wasted, if we could find out how to get that required metallographic condition with 0·04 per cent carbon, which is all that is really necessary. That is a most interesting outcome of the work which we have been doing and shows what the possibilities are. I have the feeling that we have been setting a new standard of metallurgical research in this work, and that in the future there will be a great deal of work on the large effects of small impurities.

Dr. W. Steven (Mond Nickel Company, Ltd.): One of the more interesting features of the second paper is the susceptibility of occasional batches of the iron to intergranular embrittlement. The authors present ample evidence to demonstrate that this susceptibility depends on oxygen content; nevertheless, there are indications that there are other important variables. The fact that the iron produced in the 6 lb high-frequency furnace has a lower tolerance for oxygen than that produced in the 25 lb furnace, and the behaviour of one or more of the manganese alloys, clearly indicate, in my view, other important variables, and the impression is formed that there is a critical balance between the amounts of injurious elements present and the amounts of favourable elements present, both, of course, being present in very small amounts. Minor changes in this balance can cause immunity from or susceptibility to intergranular embrittlement, and the thought occurred to me that traces of these impurities may be derived from the crucible or from the furnace linings. It was made clear this morning that a further detailed study has been made of the effect of oxygen. This would seem to be a valuable line of investigation. Not only will it resolve some of the anomalies which are apparent in this paper, but it may throw further light on the embrittlement mechanisms in commercial steel. I would emphasise that the type of embrittlement which is encountered in the N.P.L. iron may have little in common with the types of embrittlement which we encounter in commercial steels, and may be wholly characteristic of this very pure material.

Mr. B. E. Hopkins (replying to the discussion): In his remarks on the second paper, Dr. Becker said, if I understood him correctly, that he thought there was some evidence of oxygen content affecting the transition temperature even when the oxygen was present in amounts smaller than would give rise to intergranular failure. I am afraid that I do not agree with that. We have evidence which is not given in this paper, but which comes from our study of iron-oxygen alloys and which shows that for oxygen contents below that required to give intergranular failure there is no difference in properties at all between a number of irons. There are about half a dozen with oxygen content of less than 0·002 per cent, and they all give about the same transition temperature and the tensile properties are much the same. I think that our view is that oxygen contents present in amounts less than will give intergranular brittleness do not seem to have much effect on the properties. Dr. Steven said that the type of embrittlement obtained in N.P.L. iron may have little to do with the embrittlement obtained in commercial steels. There I disagree flatly, because I think that it has very much to do with it. I do not want to say very much more about that at the moment. I think that this work will in due course give us the answer to embrittlement in commercial steels, and the reason that one cannot get it from an examination of commercial steels is that there is too much variation in the impurities present, and there are too many of them

The next paper to be discussed was :—

PHYSICAL AND MECHANICAL PROPERTIES OF SEGREGATES IN TWO ALLOY STEELS

By H. M. Finniston, B.Sc., Ph.D., and T. D. Fearnehough, Assoc.Met.

Synopsis

The paper describes techniques for the measurement of hardness variation and tensile and impact properties of segregates isolated from two alloy steel forgings. The quantitative differences in properties between the segregates and the matrices surrounding them after various heat-treatments are detailed and the former are shown to be significantly harder, and to have a higher proof and maximum stress and lower elongation and impact values on all casts. The differences in chemical composition between segregate and matrix are also reported quantitatively. Photomicrographs are shown of the structures of segregate and matrix, and attention is drawn particularly to the variations in structure and concentration of non-metallic inclusions within the segregate. The influence of the inclusions on the mechanical properties of the segregate is discussed. Photomicrographs are given, which indicate the mode of formation of segregates.

Discussion

Dr. W. Betteridge (Mond Nickel Company, Ltd.): There appear to be two main factors controlling the differences in mechanical properties of matrix and segregate, and these are pointed out by the authors. There is first the differing chemical composition, which results in segregate having different transformation characteristics from the matrix, and secondly, the higher non-metallic inclusion content of the segregate. Of the various mechanical properties measured, however, the hardness is unique in being unlikely to be affected significantly by the inclusion content, so that it appears reasonable to accept it as a measure of the changes in properties solely due to the differing composition and therefore the differing hardenability of the segregate. If now the other properties measured after differing tempering treatments—the ultimate tensile stress, the elongation, and the impact strength—are plotted against the hardness values, mean curves can be obtained both for the matrix and for the segregates. If the change in properties were associated solely with the different degree of transformation the two curves should be coincident, since the authors state that the microstructures of the two types of material after hardening and tempering show little difference. In fact, it is found that the curves for ultimate stress and for elongation are displaced in such a way that, for a given hardness level, the segregates have a lower ultimate stress and lower elongation than the matrix. It is concluded that these displacements are a consequence of the increase of inclusion content. No significant displacement was to be noticed, however, for the impact values, and it would appear that the changes in impact strength between matrix and segregate after a constant treatment are solely due to the difference in hardenability. It appears unfortunate, perhaps, that the authors have so far confined their attention, at any rate so far as the results published in the paper are concerned, to steels which are essentially chromium-free—for micro-radiographic work by various authors, since this work which we are discussing has indicated that chromium is particularly liable to segregate, and, in view of its strong effect on hardenability—could be expected to have a particularly marked influence on the mechanical properties of the segregates.

Mr. D. R. Thornycroft (Mond Nickel Company, Ltd.): I can contribute further tensile test data which have been recently obtained on 18–22in diameter aircraft forgings of 1½ per cent Ni-Cr-Mo steel, which exhibited massive segregates towards the centre, but not at the rim. The segregates were harder than the surrounding matrix and were responsible for low ductility in the fully hardened and tempered material from the centre of the forgings. The loss in ductility was greater at high levels of tensile strength above 80 tons per square inch, when the segregates, although stronger than the surrounding matrix, are less ductile, and fracture occurs preferentially through their brittle structure. That mechanism of failure has been illustrated by Mr. Allsop. However, this effect was reduced by raising the tempering temperature, which induced greater ductility in the segregate, so that fracture occurred generally in the weaker matrix. The authors' longitudinal impact tests on segregates and matrices have been made on oil-hardened material of the two alloy steels. The heat-treated blocks from which the test-pieces were machined are presumably the same size as the blocks used for the hardness tests. It is probable that in this section the steels were not fully hardened in the matrix or segregate, particularly in the case of the 3½ per cent nickel steel. The incidence of transformation products other than martensite would account for the low impact values on the 3½ per cent nickel steel at the lower tempering temperatures, but if the tests were repeated on the water-quenched samples the differences between the impact values of the segregates and the matrices would probably be less pronounced.

Mr. T. D. Fearnehough briefly replied.

Finally there was a joint discussion of the following two papers :—

STRUCTURAL TRANSFORMATIONS IN THE TEMPERING OF HIGH-CARBON MARTENSITIC STEELS

By K. H. Jack, M.Sc., Ph.D.

Synopsis

New X-ray observations give direct evidence that the loss of tetragonality of martensite during the first stage of steel tempering is caused by the precipitation of a close-packed hexagonal iron carbide of composition near Fe_2C. It is proposed that this iron carbide should be named ε-iron carbide, because of its structural similarity to ε-iron nitride. The ε-iron carbide is formed as a coherent transitional phase in which relaxation of the Laue condition for X-ray reflection is a minimum in a direction normal to the (101) lattice planes. The existence of a simple orientation relationship between martensite and the hexagonal carbide is probable. During the third stage of steel tempering, ε-iron carbide transforms to give a fine dispersion of very thin platelets of cementite, with the planes of the platelets parallel to the (001) lattice planes of the cementite structure. The observed X-ray diffraction pattern is markedly different from that of high-temperature crystalline cementite, as the Laue condition is completely fulfilled only in directions parallel to the (001) planes, and is relaxed in the (001) direction. Included among the strongest reflections are those corresponding to previously unidentified X-ray reflections observed by earlier investigators and ascribed by them to a new unknown iron carbide. With increasing tempering times, or at higher temperatures, the gradual growth and recrystallisation of the cementite platelets are accompanied by reduction in the lattice strain of the matrix. Each of the two stages of the transition of martensite to cementite (corresponding to the first and third stages, respectively, of steel tempering) can take place by relatively small movements of iron atoms, and the precise nature of these movements is suggested. The proposed structural changes are correlated with the well-known changes in hardness and specific volume of steel during tempering, and are supported by recent electron-microscope studies. Cementite platelets similar to those observed in tempered martensites

are also obtained in the low-temperature heat-treatment of carbonyl-iron powders.

MAGNETIC ANALYSIS OF IRON-CARBON ALLOYS: THE TEMPERING OF MARTENSITE AND RETAINED AUSTENITE

By J. Crangle, B.Sc., and W. Sucksmith, D.Sc., F.R.S

Synopsis

During recent years, it has become apparent that the observation of structure-insensitive magnetic properties, particularly magnetic saturation intensity and its variation with temperature, leads to a useful method of investigating problems concerning metals. The method may often be applied where other techniques, such as X-ray diffraction, are less sensitive, and from its use quantitative information may be obtained about phases in alloys. In the work described in this paper the method is used to examine the phases involved when quenched pure iron-carbon alloys are reheated. Results indicate some magnetic properties of the phases and their compositions. It is shown that during the first stage of the martensite breakdown a ferromagnetic phase different from cementite is precipitated: some of its magnetic properties are indicated. Retained austenite is found to change into the same state as does martensite. After heating to 300 deg. Cent. cementite and another carbide with composition and magnetic properties similar to those of iron percarbide ($Fe_{20}C_9$) are found to be present.

Discussion

Mr. E. H. Bucknell (Mond Nickel Company, Ltd.): We are told by Jack that the three stages of tempering represent: (i) the change of martensite to ferrite, together with the coherent ϵ phase; (ii) the breakdown of residual austenite; and (iii) the conversion of the coherent ϵ phase into Fe_3C platelets and their recrystallisation into spheroids and so on. The first stage, he says, is complete at 160 deg. Cent., and third at 360 deg. Cent. Crangle and Sucksmith, on the other hand, can only explain their magnetic properties if the iron percarbide phase persists to quite high temperatures, over 500 deg Cent. I wonder whether this is just a result of the times of tempering in their work being much shorter than those used by Jack, or whether there is some deeper explanation of the apparent disagreement. One specially interesting point in the paper by Crangle and Sucksmith is the very convincing demonstration that austenite breaks down to the same products as martensite in the lower-temperature tempering range, a conclusion in which they agree with Cohen. The part of Jack's paper which I found of the greatest interest was that dealing with the structural mechanism of the tempering process. This will have given great satisfaction to all who plead for greater community of thought between research workers in the ferrous and non-ferrous fields. Dr. Jack presents a picture of the formation of cementite which runs along lines common to most age-hardening processes, with a stage of intermediate precipitation of stringlets of an intermediate body followed by the separation of two-dimensional platelets of Fe_3C before that phase takes on its equilibrium form.

Mr. D. McLean (National Physical Laboratory): I think that these two excellent papers make fairly clear the changes which occur when martensite is tempered and, taken in conjunction with recent X-ray work, it seems that the solutions given here are not likely to be changed very much. The one fly in the ointment is that there is some disagreement about the second stage. Jack suggests it is the thin plates of cementite and Crangle and Sucksmith suggest that it is $Fe_{20}C_9$. I suggest that thin plates, about 2 atoms thick, of cementite would probably not have the same magnetic properties as bulk cementite, and that the suggestion made by Crangle and Sucksmith, that one starts with Fe_3C as the first precipitate and then goes on to $Fe_{20}C_9$, richer in carbon, and comes back to Fe_3C finally, is not as reasonable as remaining at the same carbon content throughout.

The recent Russian work is available in English translations in the library and in the main agrees with Dr. Jack's conclusions.

Dr. J. Nutting (Cambridge University): I should like first of all to communicate some results of experiments which we have been carrying out at Cambridge. We have been following, with the aid of the electron microscope and the electron diffraction camera, the changes occurring during the ageing of low carbon irons. This was a material containing 0·25 per cent carbon. The carbon was first taken into solution by heating at 700 deg. Cent., which, according to the equilibrium diagram, should take into solution 0·02 per cent carbon, and then the carbon was retained in supersaturated solid solution by quenching, and then we followed the changes brought about by ageing at various temperatures.

(Here Dr. Nutting showed and commented upon some slides showing electron micrographs.)

The pattern of changes of this very low carbon material corresponds exactly with the pattern of changes observed by Jack in much higher carbon material. There is one difficulty, and that is with regard to the size of the precipitates. According to Jack's work the ϵ carbide is only two unit cells across and that would hardly be likely to give us precipitates of the size observed. That is a difficulty which we shall have to resolve. With regard to the mechanism for the breakdown of martensite proposed by Crangle and Sucksmith, from our experiments we have not been able to detect any intermediate carbide, $Fe_{20}C_9$.

It was indicated that the authors would reply in writing and the meeting ended.

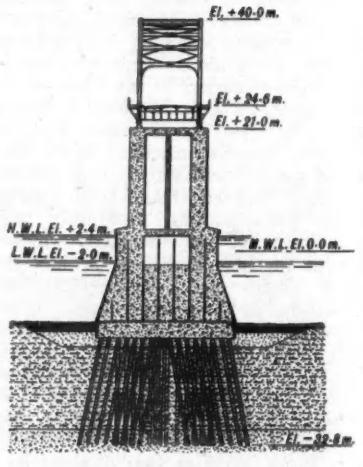
The Bridge at Vila Franca De Xira, Portugal

A BRIDGE which is probably the largest to be built in Europe since the war has just been completed at Vila Franca de Xira in Portugal. It crosses the River Tagus some 20km upstream from Lisbon, close to the site of a ferry, where the river narrows sufficiently and foundation conditions were sufficiently favourable to render construction of the bridge reasonably economical. The first bridge across the Tagus above Vila Franca is at Santarem, 80km from Lisbon, so that it will be seen that a considerable improvement in communications will result when the new bridge is put into service. The scheduled completion date for the contract is December 22nd, and the work is now substantially complete, testing of the main spans by the Portuguese authorities being in progress. It is understood that the bridge will be officially opened on December 30th by the President of Portugal, General Craveiro Lopes, supported by the Portuguese Minister of Works.

Schemes for bridging the Tagus near Lisbon have been considered several times, but were abandoned because of the width of the river and the difficult foundation conditions in the vicinity of the capital. However, tenders were called for in 1947 for a highway bridge and approaches at Vila Franca, where the Tagus is about 500m wide.

The Portuguese Government, through the National Road Board, proposed a suspension bridge with a central span of 850ft, but permitted tenderers to submit alternative designs of their own. Tenders were obtained from leading constructional firms on the Continent, from America and from this country. In view of the nationalist sentiment in Portugal, Dorman Long and Co., Ltd., tendered in association with the Portuguese firm of Seth (Sociedade de Empreitadas e Trabalhos Hidraulicos), working in a close collaboration with the Danish contracting firms of Hojgaard and Schultz A/s and Kampmann, Kierulff and Saxild A/s, both specialists in difficult marine foundation work. Dorman Long undertook the supply and erection of the steel superstructure, and "Seth" and the Danish companies the bridge approaches, piers and foundations and roadway construction.

In addition to a tender for the official suspension bridge design, Dorman Long and Seth prepared alternative designs for two other structures. Each of these designs incorporated five spans in the river crossing of 102·5m (336ft) each. In the first alternative, which has been constructed, these spans consist of tied arches, stiffened by plate girders below the bridge deck. In the second, the spans were of welded latticed bowstring truss construction. Many alternative designs were submitted by other competitors. The official suspension design proved excessively costly, one of its disadvantages being unfavourable foundation conditions at the cable anchorages, and the National Road Board decided to place the contract with Dorman Long and Seth on the basis of their first alternative design. The approximate value of the contract, which was placed at the end of April, 1948, is 120 million escudos (£1,250,000 at the exchange then in force).

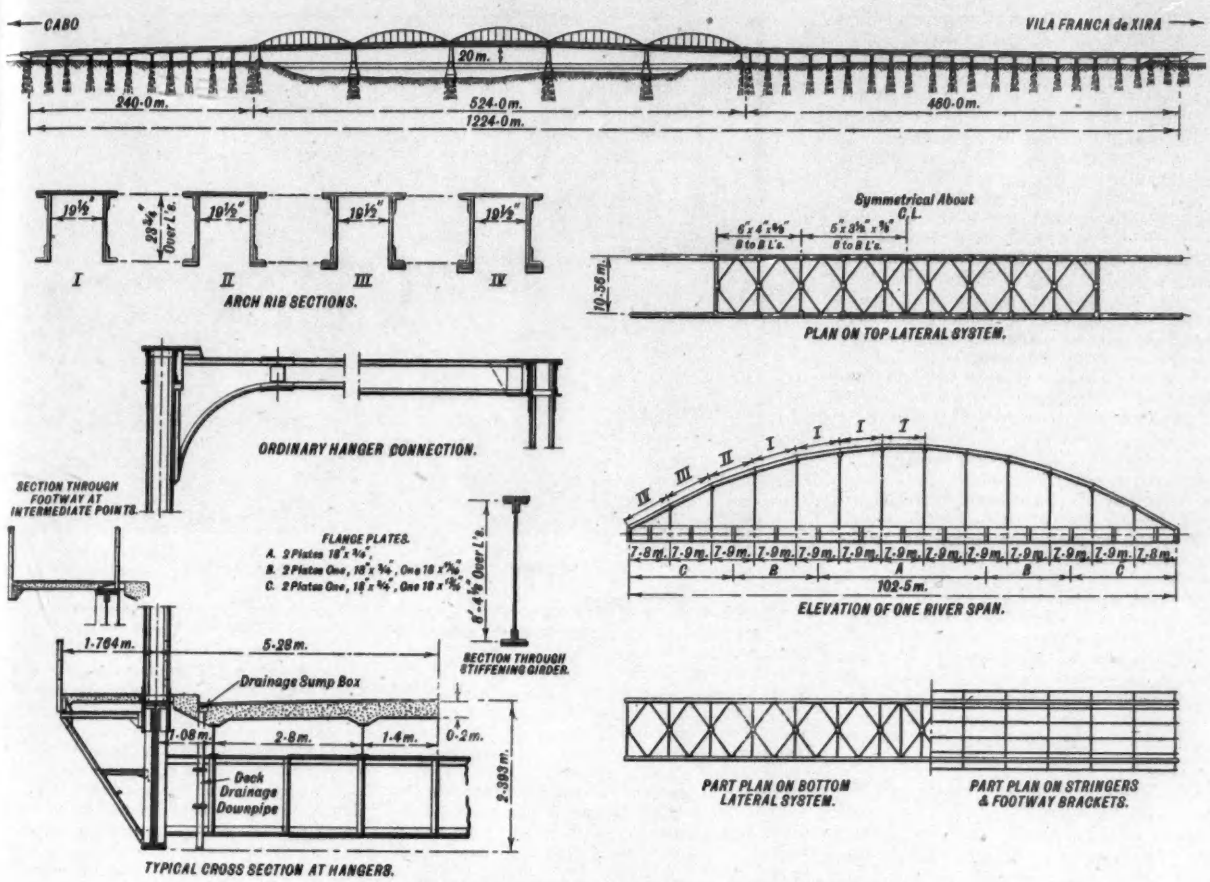


SECTION OF RIVER PIER

The leading dimensions and particulars of the bridge are shown in an accompanying illustration and the following table.

Overall length of structure	1224m
Total length of approach spans	704m
Total length of river spans	520m
Length of one river span	104m
Width of roadway	9m
Width of footways	1·5m
Clearance above H.W.	20m
Water depth at M.W.L.	13·5m
Top of arch above M.W.L.	40m
Max. length of piles at river spans	27m
Max. length of piles at approaches	36m
Structural steel (five spans)	3000 tons
Concrete	31,000 cu m
Cement	9800 tons
Reinforcing steel	3700 tons
Service span	380 tons
Estimated total cost	120,000,000 Esc.
Estimated cost of foundation and approaches	72,000,000 Esc.
Estimated cost of five steel spans	48,000,000 Esc.
Estimated time of completion	1000 days

The design is economical in steel, particularly when used with high-tensile steel for the principal structural members (the arch ribs and stiffening girders) as at Vila Franca. As may



STEELWORK DETAILS OF VILA FRANCA DE XIRA BRIDGE

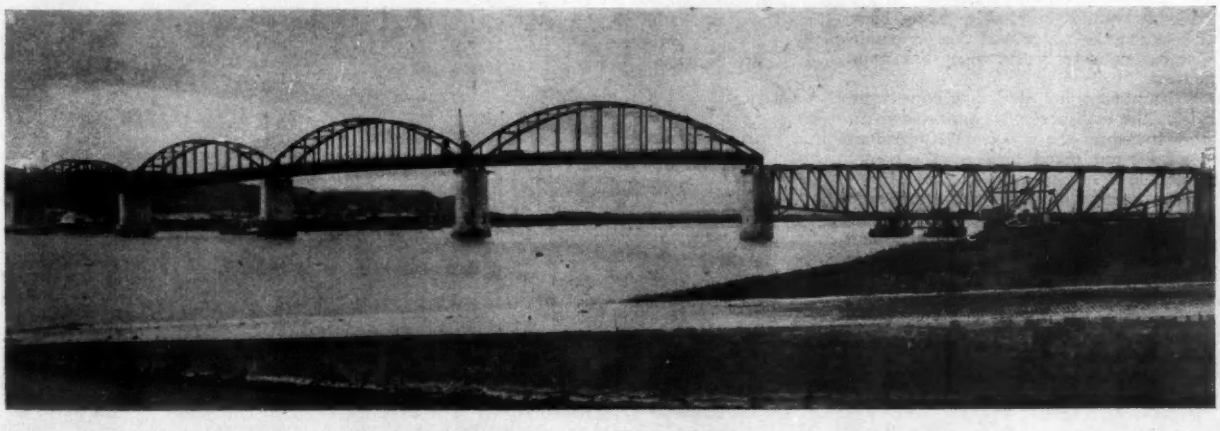
be observed from the various illustrations, the arch ribs are comparatively slender, and the stiffening girders of substantial section. The high-tensile steel was to B.S.S. 548 (maximum stress 13 tons per square inch) and the mild steel to B.S.S. 153. The overall length of the bridge structure is 4015ft and of the river crossing 1700ft; it is the largest bridge in Portugal. The bridge carries a roadway 9m wide and two footways each 1·5m wide, and is designed for heavy highway traffic, the loading conditions laid down being generally similar to those stipulated in this country. Each bridge approach consists of an earth-filled embankment followed by a reinforced concrete viaduct built in groups of three continuous beams, with spans of 20m, 25m and 20m on concrete piled foundations. Piles up to 35m long were required, and a pile was devised consisting of a solid bottom part, 25m long and 45cm in diameter, and a top part cast in situ, with a tubular steel extension which was connected to and driven together with the bottom part.

The river is approximately 500m wide at the bridge site. Its bed consists of soft silt of varying consistency for depths of up to 30m below the mean water level, below which a layer of sand and gravel provides a reasonable foundation. At the site of each river pier the silt was dredged to a suitable depth and sand filling deposited in its place. Large hollow reinforced concrete piles, 66cm in diameter, each capable of supporting a load of 120 tons and up to 27m long, were then driven from a floating staging to a bearing through the silt and into the sand and gravel layer, and left projecting through the sand filling on the river bed. The piles were made hollow to give increased frictional resistance; one of the more difficult tasks being the driving of the raker piles. A pneumatic caisson of reinforced concrete, one of which forms the base of each river pier, was then floated out and sunk over the projecting tops of the piles by admitting water as ballast. The water was forced from the working chamber by air pressure and the space enclosed by the underside of the caisson, the caisson cutting edge and the piles was filled solid with concrete. The caissons were built and launched in a floating dock especially constructed for the purpose by the contractors, since no suitable site for a slipway was available. On completion of the concreting of the working chamber, the upper compartments of the caisson were filled with concrete, working in open air, and the pier shaft was built up to its full height as shown in the cross section.

The weight of steel in the five arches of the bridge superstructure is just over 3000 tons, of which approximately 57 per cent is high-tensile steel. Two of the spans were fabricated at the Dorman Long Bridge and Constructional Works at Middlesbrough and the remaining three by Braithwaite and Co. at West Bromwich, all the steel being supplied by Dorman Long. The fabricated steelwork was shipped to the site in portions of up to 7½ tons weight and unloaded at the contractors' wharf at Vila Franca, from which it was transferred to the stockyard.

Erection

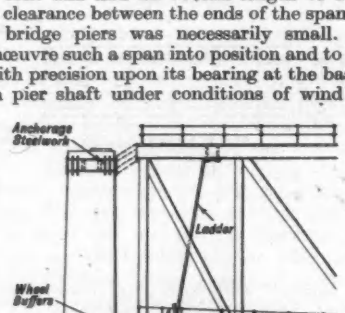
Each of the arch spans of the river crossing



VILA FRANCA DE XIRA BRIDGE WITH ERECTION TRUSS IN FIFTH SPAN

weighs 600 tons. Their erection presented a difficult problem, since the river bed is so soft and the depth to good ground so great that a normal falsework or scaffolding for the support of the spans during erection would have been very costly; also the design employed did not lend itself readily to cantilever erection. It was therefore decided to support the permanent span during its erection by a scaffold in the form of a steel service span, which could be floated into each opening in turn and left with no other support than the narrow shelf at the base of each pier shaft. Once the service span had been floated into position and landed on the piers, packings of appropriate height were laid out on top of it, and the permanent steelwork was assembled upon them by a 7½-ton locomotive crane. On completion the permanent span was jacked up at each end from the pier tops, the packings removed, the service span floated out, and the span lowered on to its bearings on the piers. Various stages in the use of the service span are shown in the three photographs reproduced herewith.

The operation of this scheme was complicated by the fact that while the length of each opening of the bridge is the same, the height from the water to the underside of the steelwork varies throughout. The tidal range is up to 4m at the site, which is subject to strong winds and tidal currents. The service span weighed 380 tons and had an overall length of 325ft. The clearance between the ends of the span and the bridge piers was necessarily small. To manœuvre such a span into position and to land it with precision upon its bearing at the base of each pier shaft under conditions of wind and



SUPPORT DETAIL OF ERECTION TRUSS

tide involved quite severe problems of navigation. The conditions were even more difficult when the service span was removed from one opening for transfer to the next, for at that time the permanent steelwork had been completed above it and was supported upon jacks from the tops of the piers. By raising the span on jacks from the tops of the piers and removing the packings upon which it had been built, sufficient clearance was provided between its underside and the top of the service span for the removal of the latter. If, however, any delay had taken place in the removal of the service span on a rising tide it would inevitably have been trapped between the water and the underside of the permanent steelwork with disastrous consequences.

Two 500-ton capacity steel pontoons were provided for the transport of the service span. They were towed to the site from Rotterdam and their hulls reinforced to carry the heavy concentrated load of the service span. Upon and between them a steel superstructure was built, the height of which could be varied to suit the clearance in the various openings. The service span was originally assembled upon this superstructure at the contractors' wharf. The pontoons, carrying the span, were then towed out and manœuvred into position opposite the first bridge opening. At this point moorings attached to the river bed and the adjacent piers were taken up and the whole outfit was warped into position between the piers at slack water at low tide. Water was then admitted to the hulls of the pontoons, sinking them sufficiently, first, to land the service span on its bearings on the piers, and then to lower the pontoons clear of its underside. The pontoons with their superstructure were then withdrawn by their moorings and removed, leaving the service span in position. The permanent span was then constructed, the stiffening girders being built first and the arch ribs and hangers after that.

WARPING ERECTION TRUSS INTO POSITION

For the removal of the service span after the completion of the permanent span above it the whole operation was reversed. As soon as the weight of the permanent span had been transferred from its temporary supports to the piers all packing, &c., on top of the service span which might interfere with its removal was cleared away. The pontoons with their superstructure were warped into position below the span at low tide already flooded to the fullest extent. The water ballast was then pumped from the pontoons by large steam pumps, with a capacity of 450 tons for sixteen minutes' pumping, allowing them to rise and make contact with the underside of the service span. Accurate adjustment of the moorings and centring and locking devices ensured that the pontoon superstructure made contact with the underside of the span at the correct points. As further water ballast was pumped from the pontoons the weight of the service span was transferred from the piers to the pontoons. When this transfer was complete the pontoons carrying the span were warped out clear of the piers and the completed span. The whole operation was carried out as rapidly as possible to avoid the possibility of the service span being trapped between the pontoons and the underside of the completed permanent span by the rising tide. Finally, the permanent span was lowered into its bearings—a roller bearing at one end and a knuckle bearing at the other.

The complete programme of erection depended upon these complicated operations being carried through smoothly; any damage to the pontoons or service span would have held up work and seriously delayed completion of the bridge. Though on several occasions it was necessary to postpone the transfer of the span due to strong winds or unfavourable tidal conditions, the operation of moving the service span in and out of each of the five openings in turn proceeded without any mishap.

The diagram shows the pin-jointed bearing assembly at one end of the service span, where it was supported on the pier. The strut *A* carried at its foot the bearing of the service span—a steel plate which rested on a corresponding plate, with locating strips round its four sides to give a slight clearance, on the pier. The strut *C* could be moved up or down through the bottom chord of the truss, allowing the tie *B* to "collapse" at the pin *D*. The erection span was moved into position with the bearing assembly in its "collapsed" position,

COMPLETED MAIN SPAN WITH ERECTION TRUSS FLOATED OUT

the strut *A* then being vertical and in line with the end of the truss, giving the maximum clearance for manœuvring, and the pin *D* being close to the bottom chord. When the erection span was in position, the strut *C* was lowered, pushing out and straightening the tie *B*; it was then pinned in position. The bearing at the end of the strut *A* was then in position ready for the erection span to be lowered on to the pier. The bearing assembly in the "collapsed" position can be clearly seen on the left-hand side of the service span in our illustration.

Bearing plates similar to the ones described above were fitted directly to the underside of the bottom chords at the other end of the erection span, the locating strips in this case, however, being omitted in the longitudinal direction to allow movement due to deflection. In the case of the centre spans of the bridge, where the clearance was greatest, struts were fixed to the bottom of the truss to carry these bearings.

Wind loading during erection due to both the service span and the permanent span above it was carried through the service span to the piers at the anchorage steelwork shown in the diagram. Four cables, each capable of taking a load of 20 tons, were fastened between the anchorage steel on the upstream side of the pier to the downstream side of the erection span; four similar cables took the load in the opposite direction. The service span was built of mild steel, but maximum stresses 25 per cent in excess of those normally permitted for a permanent structure were allowed in its design; under the full load of a permanent span it deflected a little over 4in. The permanent span was jacked up about 20in when the service span was to be removed.

Careful attention was paid to the preparation of the steel of the bridge for painting. The success of any painting treatment depends mainly upon the application of the initial priming coat to the bare clean metal, from which all rust and mill scale must be removed. In this case the steelwork was sent to the site and stacked in the stockyard unpainted to allow time for the natural weathering action to loosen the mill scale. The whole of the steelwork was then cleaned by blasting it with sand and compressed air until the surface was perfectly clean. The priming coat of paint was applied within a few hours of the completion of the cleaning process, followed by three further coats of paint. Apart from about a dozen key men from the Dorman Long bridge department, local labour was employed on the site for the erection of the main steel spans. The contract, however, secured valuable employment for the design staff of the company's fabricating shops and steelworks.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

BRONZE WELDING BY GAS

No. 1724 : 1951. This is a supplementary standard to B.S. 1723, Brazing, and has been prepared as part of the programme of welding standards authorised by the Welding Industry Standards Committee of the Institution. In addition, a request was received from the Codes of Practice Committee convened by the Institution of Mechanical Engineers and the Institution of Heating and Ventilating Engineers for standards for welded joints in galvanised pipes and copper pipes. Accordingly, the standard gives not only the requirements applicable to the process generally, but also individual requirements in respect of various applications.

Under general requirements there are included a description of the parent metals to which the process can be applied, specifications for filler metals and a system of testing procedure. The application of the process to specific parent metals, namely, copper, mild steel, galvanised mild steel, cast iron, malleable iron and dissimilar metals, is dealt with in individual sections, particular attention being given to the details of the joints. A useful set of photographs illustrating neutral, oxidising and carburising oxy-acetylene welding flames is included as an appendix. Price 3s. 6d., post free.

Institution of Mechanical Engineers

A GENERAL meeting, arranged in conjunction with the Hydraulics Group, was held at the Institution of Mechanical Engineers last Friday, December 14th, with Mr. A. C. Hartley, president of the Institution, in the chair.

The chairman said that at a meeting that afternoon the Council had unanimously elected Sir Henry Guy, C.B.E., D.Sc., F.R.S., M.I.Mech.E., an honorary member of the Institution in recognition of his distinguished scientific and engineering attainments and his outstanding services to the Institution throughout so many years.

Two Hydraulics Group papers were then presented by Messrs. A. E. Bingham and B. Cooke, and discussed.

SOME PROBLEMS OF FLUIDS FOR HYDRAULIC POWER TRANSMISSION

By A. E. Bingham

The connection between aircraft, land, and marine hydraulics is emphasised, especially regarding the working fluid and the sealing problems. The ideal fluid which would suit all cases does not, as yet, exist. The properties, advantages and disadvantages of a number of well-known, and a few lesser-known, fluids are discussed. The fluids include those based on petroleum, castor, water-glycol, halogenated, and synthetic compounds.

The properties covered include viscosity and density, and their variation with temperature and pressure; chemical and toxic effects; bulk modulus or compressibility; water miscibility, and the significance of cloud, pour, and boiling points.

The fire hazard, and its difficulties of assessment in relation to the usual recorded properties and conditions, is noted.

Thermal conductivity, dielectric strength and storage conditions are also considered.

Some of the information, of which much hitherto has been widely scattered, has been derived from recent research, and an attempt has been made to arrange the data in rational form.

LOW-PRESSURE RECIPROCATING SEALS FOR HYDRAULIC CONTROL VALVES

By B. Cooke

In tests on low-pressure oil seals the technique of designing a synthetic rubber lip type of rotary seal so that it is "run-in" on the shaft was applied to finishing the lip of a seal for reciprocating duty. The performance of a seal so treated is shown to be greatly superior to that of untreated seals. A new method of measuring the inward load was devised and is described in detail. Interesting data on friction were noted and are shown graphically.

Discussion

Mr. F. H. Towler said that, in connection with Mr. Bingham's paper, he wished to advocate hydraulic media of low viscosity. There was a great advantage in being able to stay in the turbulent range rather than in the laminar range. Most hydraulic transmission systems were largely concerned with pushing oil through pipes, but it was surprising to work out how much energy was absorbed in this work. He imagined that that was particularly so in the case of aircraft, and he hoped that his remarks and criticisms of the fluids or liquids used in aircraft hydraulics would be taken with suitable reservation.

The reason why it was of great advantage to remain in the turbulent range—that was to say, using a high velocity and low viscosity oil—was that the pipe friction varied as to the fourth root of the viscosity and when in the laminar range the pipe friction varied directly to the viscosity. The quantity that one could push through a pipe at a given velocity varied as D^2 and the pipe friction varied as the reciprocal to D^2, and the energy lost in a pipe at a given velocity was the same for any diameter pipe in the laminar range, whether it was of 1in bore or of ½in bore.

One of the principal conditions which governed the utilisation of the hydraulic liquid was the pump. If a pump operated satisfactorily, the valves and pistons would also, and a packing could be chosen to suit the liquid.

He showed a slide which indicated that, whereas in one instance a loss of 800 lb per square inch occurred at 3000 lb pressure, with a ½in diameter pipe the loss was 1600 lb per square inch at the same pressure. Half the pressure would be lost in pushing the oil through only 20ft of pipe at 20ft a second. The energy lost in the case of laminar flow was the same for any diameter pipe, but in the turbulent flow that was not true. He considered that that was a good argument.

It seemed logical to use kerosene as a hydraulic medium; it was used very widely in the engine, and therefore why not for the hydraulic system? It had availability, and it was not highly inflammable. In his pump he used aviation kerosene both as a lubricant and as the medium which was being pumped, and it had been pumped satisfactorily at 3000 lb per square inch and at 130 deg. Fah.

So far as the valves were concerned, he believed that there might be a little more danger of a hydraulic lock, but that was reduced if the size of the valve was reduced. There was less likelihood of hydraulic lock as the diameter was reduced. Therefore, if the speed were increased through the pipes, smaller pipes, smaller valves and smaller pumps could be used.

Mr. H. G. Conway said that Mr. Bingham's paper was of value because it drew attention to the factors which he considered had to be borne in mind in making use of oils for hydraulic equipment. The data on compressibility were of particular importance.

Non-inflammable fluids were coming into vogue not only for aircraft, but for general machine use, and Mr. Bingham might indicate the directions which the developments of those fluids were likely to take. Although water-based fluids were initiated in this country during the war, their development had not been proceeded with as hard as it had been in the United States.

The cost factor of fluids was one which required stressing. At present the ordinary aircraft hydraulic oil cost about 15s. a gallon, which was too high even for aircraft, and he would like to know if there was any possibility of obtaining a really cheap fluid, which would be required if hydraulic machinery was to be extended into new fields, at any rate, with the hydraulic seals available at present.

The tendency with aircraft oils was mainly towards oils which could be operated over a wide range of temperatures, say —50 deg. to 150–180 deg. Cent. At present low temperature was not such a very great problem as high temperature; but the operation of any hydraulic equipment at 150 deg. Cent. would be difficult, more particularly from the point of view of the development of suitable seal materials.

Mr. Towler had referred to the desirability of using paraffin, but he felt that the corrosion for which the fluid was responsible was a matter which ought to be gone into.

Commander J. R. D. Walker said he would like to know if there was any real evidence of fires being caused by the hydraulic fluid in aircraft or anywhere else; he could not find any.

There had been no mention of a fluid called "Argolene," which had been used fairly successfully commercially and was still

used by the Navy. It was water with a small proportion of soluble oil, mainly lanolin, and with a little sodium nitrite to act as a rust inhibitor. There they had a cheap and good hydraulic fluid. It would freeze at altitude in an aircraft, but for ordinary work it had possibilities and it had the big advantage of being cheap.

He did not altogether like the way Mr. Towler had expressed himself about the turbulent range. They did not really want to be in the turbulent range. Mr. Towler's mathematics were misleading; the virtue arose from the low viscosity. If gags were put in a pipe with laminar flow, the flow would become turbulent in certain conditions, but he did not believe that the resistance to flow would be less. What was wanted was low viscosity; and they would accidentally be in the turbulent range.

Mr. I. Paterson, B.Sc. said that when Mr. Cooke produced his paper he also presented another problem—how to find a seal with a perfect lip profile. The obvious answer appeared to be to have a moulded seal, that was, a seal which was entirely moulded, and with a moulded lip.

There could be no question of grinding the lip of a seal which had been cut, for the result was absolutely disastrous. If a seal had to be run in it had to be run in as a rotary seal on a shaft with a good surface finish.

Dr. D. Denny said he was glad that Mr. Cooke's perseverance in adapting the rotary seal for reciprocating motion had met with success. He could confirm from his own experiments in the laboratories of the British Hydromechanics Research Association that that seal had an extremely low friction effort. The only trouble was that the seals were very difficult to seal under zero or negative pressures, and even with very small pressures.

He assumed from the wording of the paper that the manufacturers supplied the ring with the correct radial loading for rotary operation. If that was so, it seemed surprising that greater loading was needed to prevent leakage when it was used for reciprocating duty.

With regard to Mr. Bingham's paper, he wished to support the author's view that the requirements of seal materials should have preference over the requirements of the liquid used. Aircraft designers in particular appreciated the importance of seals; the attitude that seals must fit in with all other requirements of design seemed to be changing, fortunately, and giving way to the view that the other components were less restricted in their requirements than the seal was. If the seal did not work, the component was more or less useless and the seal should have priority in requirements over the other materials. That position would change if more inert seal materials were to be developed, as it was hoped they would be, and then the change-over from one fluid to another would be quite easy.

Mr. E. T. Jagger said, in connection with Mr. Cooke's paper, that his company had supplied numbers of synthetic rubber packings for reciprocating shafts and they had never, prior to the author's tests, met the phenomenon of wear of the sealing lips by channelling.

In one or two isolated examples of this, it had become fairly clear that most of the wear was due directly to erosion by the hydraulic fluid flowing at high velocity through what must have been initially a minute leakage gap. That appeared to be basically the same phenomenon as was experienced in oil well pumping and which was there known as "fluid cutting." It had never been experienced with rotating shafts, even under pressurised conditions and with peripheral speeds up to ten times as great as the linear speeds met with on reciprocating rods.

General indications were that that peculiar form of wear was associated with special conditions resulting from a combination of frequency and pressure. A high frequency of operation was required and a certain amount of pressure; the higher the frequency, then the lower the pressure needed, and high pressure in itself did not induce it.

It seemed that the kind of leak which might be referred to as a sweat in an ordinary low-frequency application, and which under normal conditions would produce no wear of any note, could be transformed into a "fluid cutting" type of leak when the frequency of operation was raised above a certain figure. Presumably a high piston speed—which could, of course, be produced by a very long stroke even at low frequency—could have the same effect. It had been found, as a rough practical guide, that with ordinary strokes of a few inches a frequency of operation of up to about 60 cycles per minute did not give trouble, but higher than that difficulties could be expected depending on the precise pressure which was involved.

He thought it was highly important that low-frequency tests should be carried out before a lot of time was spent in trying to produce on a commercial basis the special packings which the author had developed.

That led to another important consideration which was summed up by the author himself when he said "the running-in process is hardly a production proposition." He would go further and say that the running-in process could never even be attempted on a production basis. Alternative methods of finishing the sealing lip would be very difficult to find, and the moulding of the sealing edge instead of the machining of it was a method which could be achieved under laboratory conditions, but it was impossible for factory production.

Mr. R. C. Worster said that he considered viscosity was the most important property of the working fluid in a system of hydraulic power transmission. It determined the power wasted in pipe friction, and thus the minimum size of pipe, which had a great effect on the total weight of the system in a large aircraft. The indefinable "oiliness" took over the importance of viscosity in lubrication problems only when viscous films broke down.

Almost all the difficulties caused by raising the working pressure in a hydraulic system could be overcome except the increasingly rapid rise of viscosity of oils at high pressures, with which Mr. Bingham had dealt in his paper. It was not important at 1000 lb per square inch, but at 10,000 lb per square inch the viscosities of most oils had risen by from three to ten times. The effect became bad at very high pressures and when doubling the pressure the pressure drop along a pipe might increase the oil flow by only 6 per cent; that, however, only happened at pressures of about 1000 atmospheres.

He considered that it was not, as Mr. Bingham had suggested, the quantity of data on the pressure viscosity effect that was small, but rather that its accuracy was poor. It was fairly certain that most measurements of viscosity at high pressures were not reliable to more than 10 per cent or sometimes even 20 per cent, and for that reason there was little hope of establishing the truth of a more general and fundamental theory on the nature of the pressure viscosity effect.

Mr. Maxwell Smith said that among the problems which beset manufacturers of hydraulic equipment during the change-over from castor base fluids to mineral oils were the unpredictable differences in behaviour of the two fluids. One of those was the phenomenon of "stiction," referred to in both papers, which had not been troublesome until then. He understood that the trouble of bonding of rubber to metal during long periods of standing idle, or, in a milder form, the increase in "break-out" force—both of which had been described as stiction—was overcome fairly soon in this country by suitable seal design and choice of rubber.

Whether the cause was physical or chemical and due to the change from natural to synthetic rubber rather than from castor to mineral fluid was not well known, and he would ask Mr. Bingham for his comments on that. It was known, however, that it was the change of fluid which caused a much more puzzling phenomenon, namely, that of the leakage of fluid past the fine clearances in hydraulic pumps, selector valves, &c.

Although no systematic examination had been carried out by his firm, a few tests had been made on samples of fluid taken from hydraulic systems of aircraft; those had all shown that the viscosity loss was fairly rapid within the first ten to thirty hours and then remained relatively constant for a hundred hours or more. That would indicate loss of viscosity due to polymer breakdown and did not influence the useful life of those mineral fluids. Not enough tests had, however, been made to be conclusive.

It was perhaps of interest to note that, where high rates of mechanical shear had existed, such as in cabin supercharger systems, the initial loss of viscosity had been recorded as high as 25 per cent. With the same fluid under milder conditions a case was recorded of a 4 per cent loss after eight hours, after which the oil remained unchanged for a period of use of 100 hours.

Mr. A. Kennaway commented on the increase of viscosity of an oil with pressure.

If oil was used as a medium for transmitting pressures of several thousand atmospheres, it was necessary to choose one which would transmit the pressure with the minimum of lag. It had been observed with certain oils that the lag got remarkably worse as the pressure rose and that there came a point where pressure was no longer transmitted. Presumably the viscosity had risen to such an extent in that case that the oil behaved as a solid.

Mr. F. J. Bradbury, with reference to Mr. Cooke's paper, said that there was no doubt at all that the ragged edges on the lips of the seals could be very troublesome, particularly in the case of experimental seals, which were frequently cut and not moulded. That trouble was even more acute in the case of seals made from hard wearing material, such as nylon.

The resultant effect on the seal of the ragged edges breaking off was probably dependent on the width of the sealing face in contact with the shaft, and it would be interesting to know that the line contact seal as used by the author gave the optimum conditions. Also, there was a great variation in the included angle of the lips of various seals being manufactured to-day, some being less than 90 deg. and some being greater.

Mr. H. E. Handyside said that from a practical point of view it must be agreed that the whole basis of selective economy in choosing a fluid for hydraulic service was its lubricating quality, its chemical stability—so that it could be put in and left as long as possible—and its optimum viscosity. Opti-

mum viscosity was a characteristic which was rather inadequate as a specification of either ideal or actual fluids.

There was also a very important point in connection with viscosity index, which was very often overemphasised. He did not think that there were very many industrial hydraulic systems in which a difference of viscosity between 85 and 100 was justified. Very few systems could apprehend that difference, and, generally speaking, viscosity indices were maintained at 60 to 85, and that was economical.

After optimum viscosity, the next primary functional quality, not industrial or commercial, was lubricating ability. The great variety of the synthetic fluids tended to obscure the basic fact that petroleum oils were lubricants, superior to those fluids which were otherwise adequately qualified for hydraulic service. The great natural disability of fluids which were better lubricants than petroleum oils was their stability, which was the reason why castor oil or castor base fluids were, generally speaking, inferior from an industrial point of view. In fact, it was very unlikely that synthetics would become of importance in the industrial field.

Wagons for Iron Ore

THIRTY special wagons are being built at the Shildon Works by British Railways for the transport of iron ore from Tyne Dock to the steel works of the Consett Iron Company, Ltd., at Consett, County Durham. These wagons, one of which is to be seen in our illustration, are the largest of their kind yet built by British Railways and are each of 56 tons capacity. They are designed to transport some 1½ million tons of ore a year between the docks and the steel works. Each wagon is carried on two four-wheeled bogies and is fitted with both power and hand braking, and power-operated side doors. These side doors can be operated simultaneously throughout a train by compressed air, under the control of the driver on the footplate of the locomotive.

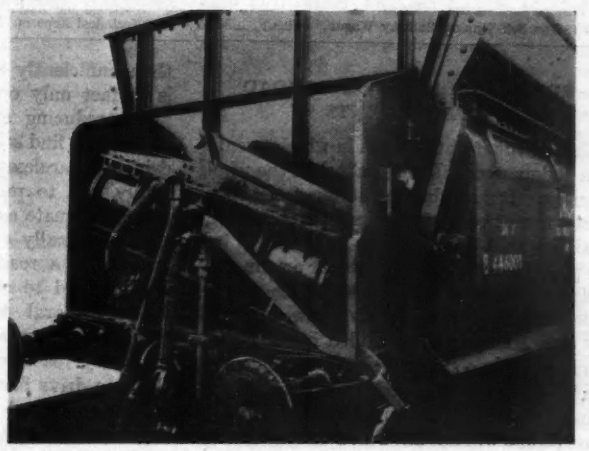
The principal dimensions of the wagon are as follows: length over buffers 36ft 5in; length over headstocks 33ft; maximum height 10ft; maximum width 9ft; bogie wheelbase 5ft 6in; bogie centres 21ft, and tare weight 28 tons 13 cwt. The body, which is in two halves with a space between for door engines, is of welded and riveted construction. Standard rolled sections have been used for the body framework and the hopper supporting frame, the plates in the sides, ends and doors being ⅜in thick and the hopper plates ½in thick. Corten steel, which has been used for the plating, was chosen as being the most suitable to stand up to the very abrasive conditions of service and also to give resistance to atmospheric corrosion. The four side-discharge doors suspended from hinges are suitably reinforced at the bottom edge to prevent distortion due to impact during loading operations.

The underframe is built up of standard 10in by 3½in rolled section channels welded together and trussing has been provided under the solebars only. The hopper supporting frame is mounted upon and welded to the underframe. Two 18in vacuum brake cylinders have been provided and the buffing and drawgear is built as near to standard practice as possible. Each buffer has nine rubber buffing springs and one rubber recoil spring, whilst the drawgear, which takes the pull immediately behind the headstock, has four rubber springs. Screw couplings are fitted and the vacuum brake hose connections are of standard pattern.

The two four-wheeled bogies are each capable of carrying 35 tons on the pivot, and although they are similar to the plate bogie developed by the Western Region they have been specially designed to meet the requirements of this particular wagon. The bogie framework is made of standard rolled sections with sole plates 1in thick. The bolster is a standard 10in by 3½in channel mounted upon four steel helical springs. Renewable manganese steel rubbing plates are fitted at the bolster horn blocks. The rolled steel disc wheels 2ft 9in diameter on tread, which can be retyred, are mounted on axles with journals 12in long by 6in diameter. The cast steel, open fronted axleboxes bolted to the bogie sole plates are fitted with standard bearings, Armstrong lubricating pads and loose oil trays. The clasp brakes have eight standard B.R. blocks per bogie and the gear has a leverage of 6 to 1.

In designing the wagons, one of the major problems which had to be overcome was the provision of suitable gear for the power operation of the side doors. Compressed air was adopted for the operating medium and as it was apparent that there was no suitable standard equipment in existence, the whole of the operating and control mechanism was designed and manufactured within the Railway Executive resources. Four sets of gear are fitted, one at each end and two in the centre of the wagon.

One set of this door-operating gear as shown in one of our illustrations, consists of two cylinders mounted on an inclined fabricated base plate. One cylinder is 14in diameter with a stroke of 12in and it serves to close the doors, whilst the other cylinder with a diameter of 16in and a stroke of 12in is used to open the doors. These cylinders are so mounted that they work in opposition to each other and so obviate any tendency to shock load the gear. Each cylinder has a piston with a stainless steel hollow piston-rod which fits on to a spigot on a triangular crosshead. This crosshead operates two intermediate or fulcrum levers, which in turn are connected to the rods which push the doors open and pull them shut. The intermediate levers are mounted on trunnion bearings. A short shaft has a shoe welded to it which engages on suitable faces of the crosshead when the doors are in the closed position. This shoe can only be operated manually and forms a lock to prevent accidental power operation of the doors during transit. The arrangement is such that the danger of twisting a pair of doors by the accidental non-operation of one mechanical lock has been obviated. As the door engines are not easily accessible for lubrication "Reservoil" bushes have been provided in all the bearings and a "Reservoil" sleeve is fitted in the cylinder head, through which the piston-rod works. Four air reservoirs 15in diameter by 40in long, together with the necessary piping and valves, are situated on the underframe. Air at a pressure of 80 lb per square inch is obtained from two compressors mounted on the locomotive.

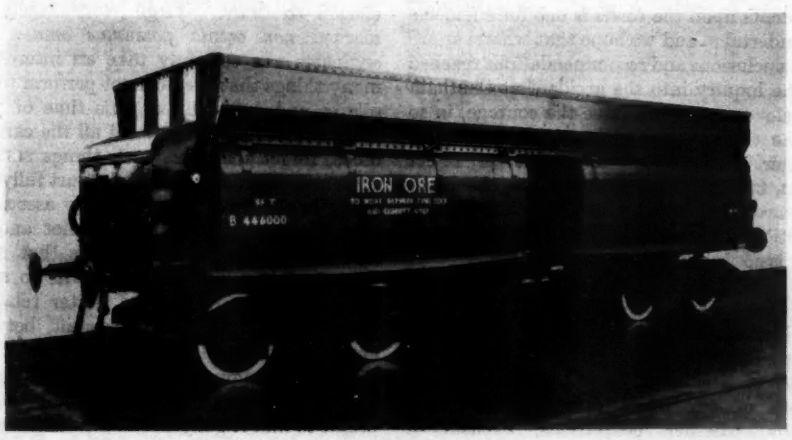


DOOR OPERATING GEAR

During a journey with a train of loaded wagons the compressors on the locomotive are kept in operation to charge the air reservoirs on the wagons. When the necessary pressure has been reached an automatic cut-out comes into effect and at this stage the pressure in the 14in diameter cylinders, in addition to the manually-operated lock, will hold the doors closed.

When the train of eight or nine wagons reaches its destination all the manually-operated locks can be released as the train slowly passes a predetermined position, to leave the doors held by the air-operated gear only. The wagons are discharged by operating a three-way valve on the engine, which causes a transfer of air from the 14in diameter cylinders to the 16in diameter cylinders, which, together with additional air from the reservoirs, will cause the doors to open.

After discharging the ore the doors are closed by setting the three-way valve in another position, which will allow the air in the 16in diameter cylinders to exhaust to atmosphere and air from the reservoirs to enter the 14in diameter cylinders.



56-TON IRON ORE WAGON

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ROAD ACCIDENTS AND ROAD IMPROVEMENTS

THE accident at Chatham in which twenty-four cadets were killed has shocked the whole country. It has shocked it far more effectively than the appalling monthly accident statistics that are regularly published, but are presented in so coldly tabular a form that their real meaning is obscured. Each month, depending upon the seasons, between about 350 and 500 people are killed in road accidents. If, as a consequence of the accident at Chatham, something effective is now done to reduce that toll of accidents on the road, those cadets will not have died wholly in vain.

Unfortunately, to judge by questions asked by back-benchers in the House soon after news was received of the accident, and by the pronouncements of certain people eminent in their own sphere, but whose views on the present subject carry no more weight than those of any other road user, the Government may find itself compelled by popular clamour to take the wrong action. Already one of our lay contemporaries has fulminated against reckless users of the roads, implicitly laying the blame for all accidents upon them. For long the Pedestrians' Association, which represents those who are the chief sufferers from road accidents, has maintained that it is sheer speed on the roads that creates accidents. It continues to campaign for an extension of speed limits. It has recently been suggested that sections of the Highway Code should be given the force of law. Numbers of people have particular "cures" for particular conditions. There are those who wish to see guard rails extended in city streets, who want Belisha crossings illuminated, who would like to see a lower speed limit than 30 m.p.h. applied in certain places, &c. No doubt there is an element of truth in nearly all such arguments. But when the nation reacts emotionally to such an accident as that at Chatham and asks that some action should immediately be taken, it is to be feared that the action favoured will be restrictive and, at least in our view, road transport is more than sufficiently restricted already. There is in fact only one sensible way of setting about reducing accidents upon the roads. It is not to find scapegoats, to blame reckless drivers or careless pedestrians, to restrict more firmly and to punish more severely. The law is adequate as it stands. It is to accept that practically every human being in this country is a road user in one capacity or another and to attempt to assess, without drawing moral conclusions about it, how people, in the mass, behave upon the roads, how they react to changes, what influences them to drive fast or drive slowly. That is coldly analytical and scientific work that engineers are best fitted to undertake. For engineers are accustomed, when a disaster befalls, not merely to blame the man, but to see whether the machine or structure or device concerned cannot be so built in the future that, whatever human failing there may once more be, such a disaster can never happen again. The Road Research Laboratory has been applying that analytical method to the behaviour of road users on the roads. Many are the interesting and valuable conclusions it is reaching as to how roads ought to be designed to suit the traffic upon them and the kind of people that use them, and as to what are the faults of existing road design. In fact, the business of reducing accidents upon the roads is one for engineers to undertake, and we hope that whatever are the conclusions and recommendations reached at the inquiry into the accident at Chatham the Government will have the courage, in so far as they may relate to road conditions, neither immediately to accept or reject them, but to submit them first to the Road Research Laboratory for the scientific and practical engineering comment that organisation is so well fitted to offer.

It is now widely admitted, amongst road engineers, that the roads of this country are no longer fitted to carry the traffic upon them, and that that is, indeed, the main cause of accidents. For the present condition of our roads demands of human beings, whether pedestrians, cyclists or drivers, standards of continuity of attention, faultlessness in judgment, and perfection in equanimity of temper that human nature in the mass is quite incapable of attaining. In consequence, most of those who suffer accidents are not those who are accident prone, but those who have never had such an experience before. It is, indeed, a sobering thought, as Dr. Glanville, Head of the Road Research Laboratory, remarked in his recent Presidential Address to the Institution of Civil Engineers, that "if conditions remain as they are, one in five of us will be injured in our lifetime. If accidents grow with traffic it may be one in three or more." In the face of such a statement and of the further fact mentioned by Dr. Glanville that the cost per vehicle mile of operating the nation's transport includes a proportion as high as 13 per cent for accidents, it seems to us astonishing that this nation is spending so little, currently, on the improvement of its roads. For is it not illogical to spend hundreds of millions of pounds annually upon a Health Service and yet barely anything upon so improving the roads that hundreds, even if not thousands, of lives would be saved and at least tens of thousands would be saved from injury, permanent or otherwise? It is, of course, true that, economically, the country would be hard put to it to find either the money or the labour to devote to the job. Yet, even if the reduction of accidents is not deemed in itself a sufficient justification for the expense, there are high economic gains to be expected, too. How high they would be it is not easy to assess, and one of the tasks to which the Road Research Board has set its hand is the illumination of that question. It is, however, certain that an improvement of the roads and of road transportation, which, upon Dr. Glanville's estimate absorbs 8 to 10 per cent of our industrial potential as against 3 per cent by the railways, must help the whole economy of this nation. May it soon be given to road engineers to start upon that work of improvement which, sooner or later, will have to be undertaken, and which they are so willing and eager to begin!

FESTIVITIES

RIGHTLY or wrongly, the engineer is sometimes regarded by those in other professions as of a class apart, wrapped up in his work, and with but little time to devote to the political or social world, generally characterised, in fact, by a spirit of aloofness from his fellows. Surely it is a very erroneous conclusion to draw. Virgil very sagely remarked *non omnia possumus omnes*, but engineers can certainly take an interest in many things that they cannot perform themselves, and especially at this time of year most of them gaily throw off all the cares of office, forget there are such things as slide rules and protractors, and take part fully and freely in the festivities so largely associated with Christmas. But is there not another side to the picture, and that is that these very festivities may contribute in no small way to the establishing of better relations between a manager and his staff, between employer and employed?

Many managing directors, on going into an office on Christmas Eve, might be surprised to find it gaily decorated. For not all office staffs like to incur the expense and

trouble involved. But most offices on the last working day before Christmas are pervaded with a spirit of gaiety and brightness not usually found there; and managing directors usually relax somewhat themselves, enter into the spirit of the thing, chat in a friendly way with the staff and wish them a Merry Christmas and a bright and prosperous New Year. But does not the whole thing raise in the mind a question as to whether something might be done to preserve some of this cheerfulness in the more conventional days that are bound to follow. Many engineering offices are drab and distinctly dreary places that could easily be brightened without undue expense, and a little more attention could be paid to the comfort of workers in the office, indeed, also to those working at a machine or on the bench. Something has been attempted in this direction by many firms. But has it been enough attempted? Need we limit the thought of festivity to any one period of the year?

Engineers know from experience the value of the big dinners organised so efficiently year by year by our leading professional institutions, and how they promote new friendships and cement existing ones, while increasing the appreciation of our profession in its manifold character. Valuable as they undoubtedly are, they are necessarily of a formal character, and perhaps occasional informal gatherings in which greater freedom might obtain would help to afford the opportunity of useful contacts between senior engineers, and those who are only on the lower rungs of the professional ladder. The reunion dinners held by old students of our engineering colleges are now an established custom. They enable past students to keep in touch with their old college in a very enjoyable manner, and to learn of the advances made in the teaching profession. But why limit this idea to colleges and institutions? Why not extend it to the factory and workshop? We could cite a few engineering works that do arrange for dinners for past and present students, and very interesting those gatherings prove to be, but again we say, does this go far enough? More opportunities for retired employees to spend a convivial evening with their successors might lead to a useful exchange of views, and even if the old stager might be prone to observe that "the old is better," the present employee might gain a good deal by a friendly chat with one who had gone before and had a wealth of experience. There are many other ways in which the spirit of "goodwill to all men," if more continuously fostered throughout the year, might prove of permanent value, not only to the work of the individual, but to that of the whole organisation.

Obituary

BERNARD M. JENKIN

As briefly recorded in our last issue, the death which occurred, at Bristol, on December 3rd, of Mr. Bernard Maxwell Jenkin, who for many years practised as a consulting engineer with the late Sir Alexander Kennedy. Mr. Jenkin was eighty-four.

Bernard Maxwell Jenkin was the youngest son of the late Professor Fleeming Jenkin, who was the first holder of the Chair of Engineering in the University of Edinburgh. In his early days, B. M. Jenkin was on the electrical engineering staff of the London and North-Western Railway, but he relinquished that appointment in 1891 to become Sir Alexander Kennedy's assistant. In 1899, he entered into partnership with Sir Alexander in the consulting firm known as Kennedy and Jenkin, a firm which continues to practise under the style of Kennedy and Donkin.

With Sir Alexander Kennedy, Jenkin took a prominent part in the design of many electricity supply and traction schemes in this country and in India, all of which were characterised by his scholarly mind and progressive outlook. He was elected an associate member of the Institution of Civil Engineers in 1892 and a full member in 1902, and in 1886 he became a student of the Institution of Electrical Engineers, to membership of which he was elected in 1898. Mr. Jenkin's papers to the Institution of Civil Engineers included one dealing with the electrical equipment of the Waterloo and City Railway, with the design of which he was closely concerned. For that paper he was awarded a Telford Premium. He also presented to the "Civils"—in collaboration with Mr. W. M. Mordey—a paper on "Electric Traction on Railways," the discussion on which created a record by extending over five meetings of the Institution. Mr. Jenkin received the George Stephenson Medal for the paper.

For health reasons, Mr. Jenkin retired from his consulting engineering work in 1913, and then successfully turned his attention to scientific farming. He continued in that occupation until advancing years prevented him from giving that personal attention to detail which was evident in all the work he undertook throughout his long professional career.

Literature

Foremanship. By F. J. Burns Morton. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 25s.

The foreman envisaged by Mr. Burns Morton is somewhat of a paragon; indeed, among the many we have met not one has by any means approached the ideal presented, but this fact does not in any way detract from the wisdom of setting a standard of perfection, especially seeing that we cannot help agreeing that "the foreman in British industry . . . is inclined to become conservative in outlook." For this very reason it is desirable to place in his hands a textbook that will afford him the opportunity of enlarging his knowledge, and the book before us will give the intelligent foreman an insight into the general organisation of the business of which he forms an integral part.

To give a general idea of what the author suggests the foreman should have acquaintance with, a general survey of this book is required. There are twelve chapters of which the first gives a concise examination of what is involved in supervision, and the progress that has been made by rendering it more scientific in principle, while in the next chapter we pass to the problem of organisation in which attention is properly drawn to the fact that it is never static, but rather a continuous process leading to reorganisation. The third chapter is devoted to management, stress being laid on the necessity for understanding people, starting employees in a suitable manner, and settling grievances as soon as they are brought to notice; in the fourth chapter we proceed to operation control, including such matters as time studies, prevention of waste, and general efficiency, this being the first step in production control which is considered in Chapter V; in this connection the author advocates foremen becoming alive to the necessity of being ever on the look-out for labour-saving means, and he suggests that "trade papers provide ample advertisements of equipment," but perhaps he does not realise that many managers still try to keep such journals from their staff lest they see advertisements for employment elsewhere, surely a very unenlightened policy. In the matter of quality control (Chapter VI) it is stated as an axiom that quality always comes before quantity, a sound principle often overlooked, and the relation between foremen and inspectors is discussed; though we are glad to note that inspection is placed under the general manager, and not the works manager as, unfortunately, is sometimes the case. Chapter VII introduces the important question of cost control, and after reading it a foreman may perhaps realise for the first time the value of a good system of cost accounting and how it can help him rather than be a whip to scourge him. The remaining chapters handle questions of personnel, including the training of employees (Chapter VIII), leading to greater skill and more effective work, this being followed by an investigation into the value of incentives (Chapter IX), both financial and non-financial, and some of the pitfalls likely to be encountered. Chapter X discusses labour management, a bugbear to the old-time foreman who bitterly resented being deprived of the power to select and discharge his men, but he is shown how he can co-operate and be the means of overcoming excessive labour turnover as well as reducing absenteeism in his own department. If working conditions (Chapter XI) are to a considerable extent outside his immediate control, a foreman can do much by careful observation and judicious recommendations to prevent accidents, to ensure comfort to those entrusted to his charge and to help build up that morale which is so invaluable in every industrial establishment. Chapter XII is concerned with leadership which the author defines as "the ability to get the best from people," and certainly good leadership tends to get good results, for the majority of operatives strongly resent bullying tactics, but are amenable to the suggestions and guidance of someone whom they instinctively feel they can trust.

We are told there are four steps in the solving of all problems: they are finding the facts, deciding on action, consulting and explaining, and getting results. Perhaps the third step is the most important for many good systems have come to grief because those who will have to work them have not been consulted and do not understand what is required of them. It is generally desirable to enlist the sympathy of the humblest member of the team and to do everything possible to dissipate the antipathy to change that is found in most of us.

In looking into the future the author suggests that "more than in any other function in business the foreman is in daily contact with a fast-moving social and productive organisation," which must involve improvements in technique and methods, and for this very reason the leader in the workshop needs skill acquired through training and experience and the development of character.

An appendix on reading gives advice as to how to read, how to study and take useful notes, while finally there is a bibliography

arranged in the order of the different chapters of the book; this might with advantage be enlarged.

Mr. Burns Morton indicates the advisability of a foreman maintaining self-improvement, but we should welcome more concrete proposals as to how this may be done. It is well to suggest his moving from department to department, but this can only be effective if arrangements are made to ensure a measure of interchangeability. We would suggest informal meetings of foremen who can, on such occasions, freely express their views without fear of official criticism and, at the same time, gain an insight into the problems of others.

Undoubtedly, every foreman, however seasoned he may be, will derive much benefit from a careful study of this very useful book, even though it may lead to much serious heart searching. If industry generally is to benefit, the higher executive might with advantage scan its pages with a view to removing some of the obstacles that beset a harassed foreman and to ensure him a place as firmly identified with the management.

Locomotive and Train Working in the Latter Part of the Nineteenth Century. Vol. I. By the late E. L. Ahrons. W. Heffer and Sons, Ltd., Cambridge. Price 15s.

"Of all those who worship at the shrine of the steam locomotive, there has never been one more devout and more learned than the late E. L. Ahrons." So wrote Mr. Loughnan Pendred in 1927 in a foreword to the publication of Ahrons's classic work, "The British Steam Locomotive, 1825–1925." Before that, however, Ahrons had endeared himself to railway and locomotive enthusiasts all over the world by the famous series of articles in *The Railway Magazine*, a first selection of which have now been reprinted in book form. The series began in January, 1915, and had its immense popularity been foreseen it is fairly safe to say that many of the earlier instalments would have been on a more extended scale. As it was, the London and North-Western Railway—the first to be dealt with—was covered by four articles, the Great Northern by no more than two, whereas in 1919 and 1920, when it came to the turn of the Midland, Ahrons received editorial blessing for no fewer than eleven articles on the latter railway.

Those who have edited the present volume had no choice but to adhere to the original script, with the result that the Great Northern and the Manchester, Sheffield and Lincolnshire, which came early in the original series, are treated in much more abbreviated style than the North-Eastern and the Great Eastern. With the Great Northern in particular there is no mention of any locomotives designed by H. A. Ivatt, with the result that one of the most outstanding of nineteenth century types, the first British "Atlantic," built at Doncaster in 1898, is omitted. But while considered as a single entity, this first volume of the reprints does show a certain lack of balance, the articles themselves are a sheer delight, coming once again as fresh, informative and witty as the present reviewer remembers them, as one by one they were published thirty to thirty-five years ago. In addition to the four large railways mentioned earlier this first volume also includes the Hull and Barnsley, and the Midland and Great Northern Joint, and it was with some of these smaller concerns that Ahrons rose to such heights of humorous description, while never foresaking technical accuracy.

The republication of so brilliant a collection of articles, depicting so vividly the late nineteenth century railway scene in Britain, is assured of a wide welcome, especially as the first volume is beautifully produced and finely illustrated. To the work of editors and publishers we would add our congratulations to Mr. C. R. H. Simpson, of the Locomotive Publishing Company, Ltd., under whose supervision the selection of photographs for illustration was made.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE END OF AN ERA

Sir,—Mr. Livesay's delightful articles on the Canadian Pacific Railway in the mountains have so far made no reference to the section which has always seemed to me the most interesting of all—the original line down to Field, which dropped into the Kicking Horse valley on the sensational gradient of 237ft to a mile, say, 1 in 22. A journey up or down this very steep hill was exciting at any time; on a dark night it was an adventure never to be forgotten. As more than forty years have now passed since the old line was abandoned in favour of the present deviation, with its much easier grading, and there can be few still surviving who worked on the line in the last century, if Mr. Livesay has any figures showing the performance on this fearsome bank of the small locomotives which were then in use, it would be good to have them on record before the whole story has faded from memory. Part of the old track was incorporated into the modern highway and the motorist who drives over it to-day, if he thinks of the matter at all, may wonder why so much fuss about a mere 1 in 22! But railwaymen who know the effect on Bristol to Birmingham traffic of our own short length of 1 in 37½ at Bromsgrove will appreciate the skill and meticulous care which were required to keep the trains moving in all kinds of Canadian weather to and from Field.

Other standard gauge lines in the Rockies, such as the Cripple Creek and the Colorado Midland, which had gradients of more than 200ft to a mile, have also been closed and abandoned; and if the steam locomotive itself is now to be discarded much of the attraction of travel in that part of the world will have gone.

W. B. Thompson

The Athenæum, Pall Mall, S.W.1,
December 16th.

Productivity Report on Coal Mining

The latest report to be published by the Anglo-American Council on Productivity is one containing the findings of a specialist team which visited the U.S.A. in March and April last to study the American coal mining industry. The team, which consisted of sixteen people employed in various capacities by the National Coal Board, was led by Mr. E. L. Chiverton, vice-chairman and production director of the South-Eastern Divisional Coal Board. The report states, however, that the tour was not to be regarded in any way as taking the place of visits to the U.S.A. by National Coal Board specialists.

During its tour the team visited twelve mines, two large central coal cleaning plants, three factories making mining equipment and one making safety equipment. In addition, the programme included several conferences with associations and trade unions connected with the American coal mining industry. In presenting its report, the team has pointed out that there are over 9000 mines of commercial size in the U.S.A., or nearly ten times as many as in Britain.

Superior geological conditions and the vast extent of the coal reserves of the U.S.A. give the American mining industry a character very different from that of the British industry, and the team agrees that there can be no question of introducing American methods and machines wholesale into Britain. It suggests, however, that there is much to learn from the best American practice.

The principal chapters of the report deal with management, labour, production and safety. That on production contains a fair amount of detail on such important matters as methods of working, equipment, mine ventilation, roof bolting, shotfiring, transport, power supply, maintenance, coal preparation, and surface lay-outs. Summarising its observations on coal preparation, the team says that standards of equipment in the newer plants are high and the tendency in the U.S.A. is to employ large staffs to control the processes. But, the team adds, "we met no processes or equipment unknown to British practice, and have no specific recommendations to make."

The summary of the team's general findings and recommendations occupies five pages of the report. It emphasises, for instance, that the British coal mining industry should give particular attention to the systematic training of management to make use of modern techniques and aids and to function as a team, and suggests that the success of mechanisation depends as much upon the proportion and quality of supervision as upon mechanical ingenuity. Above all, the team advocates the desirability of inspiring and helping colliery management to initiate experiments and innovations. On the important subject of mining manpower, the report urges the British coal mining industry to recognise that it takes from two to three years to get the most out of a particular combination of man and machine. It says that training must thus be regarded as a continuous process, which, though well started at schools and in the industry's own training centres, can only be completed on the job. On production methods the team's comment is: "Rather than machines, we should like to see injected into the British industry the sense of adventurous urgency which characterises the American attitude towards development, and is found in management and men alike." Although the team recognises the problems of completely mechanising longwall working, it does not consider that they are technically insoluble. The need, the report says, is for a concerted drive to bring to longwall working the degree of mechanisation achieved by the Americans in room-and-pillar working. The team thinks that the National Coal Board should intensify its efforts towards the development of new machines and techniques and should stimulate, harness and reward local inventiveness.

Finally, the report observes that the American coal mining industry is carrying out experiments in many fields, and the team suggests that it would be imprudent not to keep in touch with them. It recognises that valuable links between the American and British industries have already been established, but it nevertheless suggests that the general question of setting up liaison machinery of a permanent nature should be examined at a high level.

The report may be obtained from the Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1, price 3s. 6d.

BOOKS RECEIVED

Electric Domestic Refrigerator Handbook. London: British Electrical Development Association, 2, Savoy Hill, W.C.2. Price 5s.

Technology of the Machine Shop. By H. C. Town., London: Longmans, Green and Co., Ltd., 6 and 7 Clifford Street, W.1. Price 21s.

Belt Drives in the Small Workshop. By "Duplex." London: Percival Marshall and Co., Ltd., 23, Great Queen Street, W.C.2. Price 3s. 6d.

How to Build That Garage—Workshop. By T. E. Dutton. London: Percival Marshall and Co., Ltd., 23, Great Queen Street, W.C.2. Price 5s.

Water Treatment for Industrial and Other Uses. By Eskel Nordell. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 80s.

A Steel Plate Thickness Meter

By S. S. CARLISLE. M.Sc., A.M.I.E.E.,* and B. O. SMITH, B.Sc.*

Summary

THIS article describes a portable instrument for measurement of the thickness of steel plates requiring access to one side of the plate only. It employs a magnetic method. The measuring head of the instrument consists essentially of a pot-shaped electromagnet with provision for indication of the total magnetic flux in the main magnet circuit. On application of the electro-magnet to the plate under examination, saturation flux density is produced in the body of the plate and the total flux indicated is directly related to the plate thickness. The range of the instrument is 0–0·25in with an overall limit of error of ±0·003in, or ±3½ per cent, whichever is the greater. The instrument reading is little affected by the presence of paint or rust coatings up to 0·015in thick on the plate surface. Surface roughness or pitting has little effect on the reading.

The article also briefly describes the resistance, ultrasonic and other magnetic methods of measuring the thickness of metal plates from one side only and points out the advantages of the magnetic method adopted.

Introduction

In routine inspection and research in industry many problems arise in connection with the measurement of metal thickness, such as in the determination of steel sheet thickness, pipe wall thickness or the wall thickness of a storage vessel, such as a tank or gasholder.

In most cases it is inconvenient, if not impossible, to make contact with more than one face of the sheet or wall being studied. As a result many and varied techniques have been developed to enable a thickness measurement to be made under conditions where only one face of the material being studied is accessible. Among these techniques might be mentioned the following :—

(1) *Resistance Methods.*[1, 2, 3]—The thickness of the material is determined from a measurement of the electrical resistance introduced between a pair of electrodes placed in contact with the surface at a suitable distance apart. Although fundamentally very satisfactory, this method has a limited application, because it entails the measurement of very small d.c. potentials, which requires delicate measuring instruments. Also the good electrical contact necessary between the probes and the surface of the material is often difficult to realise owing to corrosion or protective coating on the surface.

(2) *Magnetic Methods.*—In one kind the thickness of the material is determined from a measurement of the magnetic reluctance of a portion of the plate when placed in contact with a laminated yoke carrying a magnetising winding. This method has been employed with both a.c. and d.c. excitation,[3, 4] but with the former the thickness that can be measured is limited by the depth of penetration of the a.c. flux. Both methods suffer from the disadvantage that the calibration is dependent on the permeability of the material of the plate which can vary over a very wide range according to its composition, magnetic history and work-hardening. A variation of this method has been developed by the General Electric Company of America, in which d.c. excitation is used, but the magnetic induction is increased until saturation is reached. By this means the instrument calibration is not dependent on the permeability of the material, but only on its saturation flux density.

(3) *Ultrasonic Methods.*[5, 6]—A continuously excited crystal transducer is applied to the surface of the plate, so setting up in the material a mechanical vibration usually at supersonic frequency. There will be a particular frequency and harmonic series at which mechanical resonance is set up through the thickness of the plate due to the interference of the direct vibration wave and that internally reflected from the opposite face. From a knowledge of the frequency and its harmonics at which this resonance occurs the thickness of the plate can be deduced. This method can only be satisfactorily applied when the surface conditions of the material being examined are very good both on the application face and the inside face.

The problem presented to the authors which initiated the development of the instrument described in this article was concerned with the measurement of the thickness of residual metal in a heavily corroded steel sheet of which only one face was accessible. For this particular application it was considered that the only method of these listed above likely to be successful was the magnetic saturation method. The instrument described, although employing a similar principle to that previously used, is thought to show a considerable improvement in the method of measurement of the magnetic induction. Also, the effect on the instrument reading of coatings such as paint or rust on the surface of the material being studied have been appreciably reduced in this instrument.

Development of the Magnetic Saturation Method

An examination of the saturation flux densities for various carbon and alloy steels shows that this parameter is closely related to the material composition and is reasonably constant for a particular steel. In the case of carbon steels, it varies very little with carbon content and is unaffected by heat-treatment. Heat-treatment does, however, have a small effect on the saturation flux density of the low alloy steels, Fig. 1. It was therefore considered reasonable to adopt the method of thickness measurement based on a determination of the total magnetic flux which a section of the material can carry at saturation.

To analyse the performance to be expected of an instrument operating on this principle,

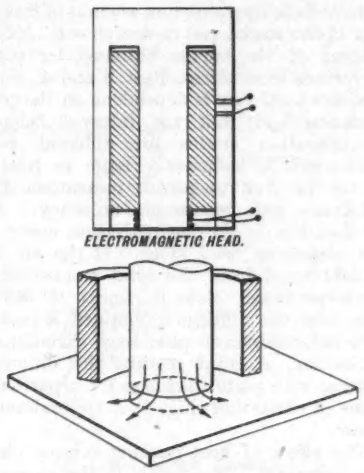


FIG. 2—EXPERIMENTAL MEASURING HEAD

an experimental measuring head in the form of a pot-shaped electromagnet, as shown in Fig. 2, was made. Considering this electromagnet placed on the surface of a plate, it will be seen that as the excitation is increased a condition will be reached where saturation flux density, $\hat{B}$, is set up in the surface of a cylindrical wall of the plate material immediately beneath the pole, as shown in Fig. 2. This assumes that the magnet core is unsaturated. Since the section area of the magnet core is πr^2, while the area of the cylindrical wall in the plate beneath the pole is $2\pi rt$, where t is the thickness of the plate being studied, it is necessary that r be appreciably greater than $2t$ to ensure that saturation of the pole does not take place, assuming equal values of $\hat{B}$ for the material of the pole and the plate. From a measurement of the magnetic flux traversing the centre pole or the outer annulus, the thickness of the plate could be deduced approximately, knowing $\hat{B}$ for the material. Since, however, the relationship between total pole flux and plate thickness can only be approximately calculated, due to the effects of leakage flux, fringing flux and imperfect saturation of the material due to the finite value of

MATERIAL	ANALYSIS TOTAL C.	Mn.	S.	Si.	P.	OTHER	TEMPER
WHITWORTH	0·09	0·15	0·016	—	0·042	—	ANNEAL
MILD STEEL	0·32	0·438	0·017	0·042	0·035	—	"
" "	"	"	"	"	"	—	OIL HARDEN
" "	0·89	0·165	0·005	0·081	0·019	—	ANNEAL
" "	"	"	"	"	"	—	OIL HARDEN
MANGANESE STEEL	0·674	4·73	0·023	0·608	0·078	—	AS FORGED
"	"	"	"	"	"	—	ANNEAL
"	"	"	"	"	"	—	OIL HARDEN
"	1·298	8·74	0·024	0·094	0·072	—	AS FORGED
"	"	"	"	"	"	—	ANNEAL
"	"	"	"	"	"	—	OIL HARDEN
CHROME STEEL	0·532	0·393	0·02	0·22	0·041	0·621 CT	AS FORGED
"	"	"	"	"	"	"	ANNEAL
"	"	"	"	"	"	"	OIL HARDEN
"	0·687	0·028	0·02	0·134	0·043	1·195 CT	AS FORGED
"	"	"	"	"	"	"	ANNEAL
"	"	"	"	"	"	"	OIL HARDEN

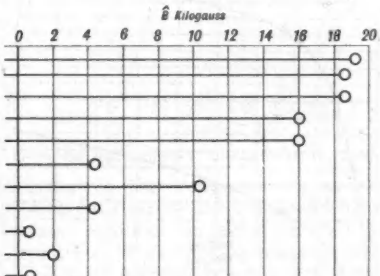


FIG. 1—SATURATION FLUX DENSITY OF HEAT TREATED LOW ALLOY STEELS

* Physics Department, Instruments Section, British Iron and Steel Research Association. This work was carried out on behalf of the Magnetic and Electrical Methods sub-committee of the British Iron and Steel Research Association.

magnetomotive force in the circuit, an experimental calibration of an instrument operating on this principle will be necessary.

A magnetisation curve for the measuring head with a test plate in position was determined by the method of reversals using a ballistic galvanometer for flux measurement. The search coil was placed as near to the open end of the pot magnet as possible, so as to include the minimum amount of leakage flux in the search coil measurement. Examination of the curves obtained for plates of various thicknesses, Figs. 3 and 4, shows that the total flux is dependent on the plate thickness and that the interval between magnetisation curves for different plate thicknesses is sufficiently large in relation to the air flux to permit measurement of thickness with reasonable accuracy. The air flux line is the magnetisation curve for the measuring head alone. If the air flux is subtracted from the total magnetisation for a particular plate thickness, it will be seen that the difference obtained is reasonably independent of quite large variations in excitation. A graph relating this difference reading with plate thickness for a particular value of excitation (Fig. 4) is approximately linear.

The effect of heat-treating sample plates was examined. No change in the measured value of thickness was observed on heating carbon steels to over 900 deg. Cent. and quenching in water, thus confirming the independence of saturation flux density of carbon steels on previous heat-treatment.

It is apparent from the curves of Fig. 3 that if the air flux is small compared with the magnetic induction in the plate being examined, then the estimate of plate thickness

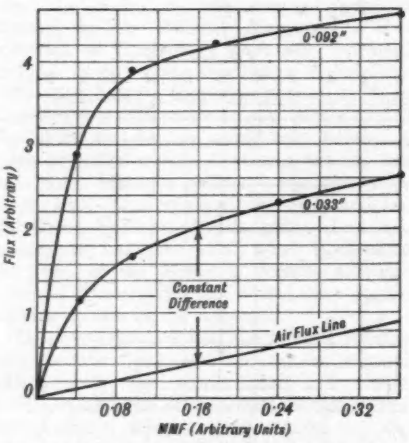


FIG. 3—RELATIONSHIP BETWEEN FLUX AND MAGNETOMOTIVE FORCE

based on the value of total flux in the pot magnet pole will be little affected by changes in the excitation current. Also, the presence of a small air gap between the plate and the magnet such as might be caused by a rust coating will have little effect on the total flux provided that the excitation is sufficient to overcome the gap reluctance and still maintain saturation flux density in the plate. Experiments with this simple pot magnet unit showed that a gap of about 0·004in could be introduced without appreciable effect on the estimation of plate thickness. This characteristic of the measuring technique is discussed in more detail later.

Some experiments were carried out to determine the effect of scale formation on the accuracy of thickness measurement. A sample plate 0·053in thick was heated for a sufficient time to form a scale of approximately 0·01in. Subsequent measurements on this sample showed no detectable effect of the scale formation on the thickness measured.

A study was made of the methods available for measurement of the flux in the magnet pole. The search coil and flux meter method used in the early experiments was not considered suitable for use in an instrument ultimately to be designed in a portable form for field use. Consideration was given to the use of a bismuth wire element or a pivoted magnetometer. The former method is capable of quite high sentitivity, but considerable precautions have to be taken to make the device independent of temperature changes.[7] A pivoted magnetometer has been used for quite a number of purposes, for example, in the testing of magnets,[8] but it has the

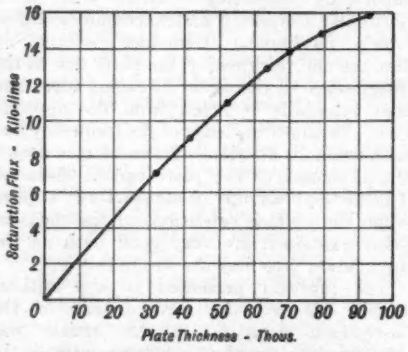


FIG. 4—RELATIONSHIP BETWEEN SATURATION FLUX AND PLATE THICKNESS

disadvantage of a very limited range over which the angular rotation is linearly related with the flux density.

The method finally adopted and found very satisfactory used a moving coil element energised with a fixed current to measure the magnetic flux in a secondary magnetic circuit which was shunted across a small air gap in the main magnet circuit. The arrangement is shown in Fig. 5. The angular deflection of the moving coil element is a direct measure of the flux in the main magnetic circuit and the relationship between the meter deflection and the plate thickness can be controlled by adjustment of the moving coil current. Thus the instrument calibration can be readily adjusted for materials of differing values of B. The gap in the main magnet circuit need only be very small so that little extra M.M.F. is required to overcome its reluctance.

A particular advantage of this method of measuring the total flux is that the air flux in the main circuit can be completely compensated by injecting into the secondary flux circuit a sufficient M.M.F. to give zero deflection of the moving coil in the absence of a specimen plate. This M.M.F. can be provided by coils C, wound on limbs of the secondary circuit, as shown, and connected in series with the excitation coil. The compensation holds over a wide range of excitation currents when no test plate is present. When a plate is being measured, however, the compensation is only effective over a limited range of excitation current and this range is dependent on the thickness of the plate being measured. The compensation only holds while the flux in the main magnet circuit is linearly related to the energising M.M.F. and this linear relationship ceases to exist when the flux density in the pole approaches saturation value. The effect is shown in Fig. 6, which depicts a series of calibration curves for various excitation currents. The curvature of the calibration curve is due to approaching saturation of the centre pole of the pot magnet and, as indicated earlier, this curvature appears when the thickness of the plate being measured approaches half the radius of the centre pole. To obtain a reasonably linear calibration curve, it has been found that with annealed soft iron as the pole material it should have a radius of at least three times the maximum thickness of plate to be measured. This feature of the instrument design tends to limit its application to plates below $\frac{1}{2}$in thick, because for sizes greater than this a very large and cumbersome measuring head would be required.

The effect on the instrument reading of a gap between the measuring unit and the plate surface has been studied with various designs of measuring head. This effect is primarily controlled by the magnitude of the air leakage flux in relation to the saturation induction in the plate under examination. The air leakage flux should be as small as possible in proportion and this condition can be satisfied by providing a large annular space between the centre pole and the outer annulus. Design of the centre pole section area to maintain a relatively low value of maximum flux density so ensuring a linear calibration curve also reduces the error in the instrument reading resulting from a gap between the measuring head and the plate surface. In the course of experiments it has also been observed that the shape of the curve relating percentage error in the instrument reading with magnitude of the gap between the measuring head and the surface can be varied by adjustment of the reluctance in the secondary magnetic circuit. This reluctance can be readily adjusted by introducing air gaps in the secondary circuit or

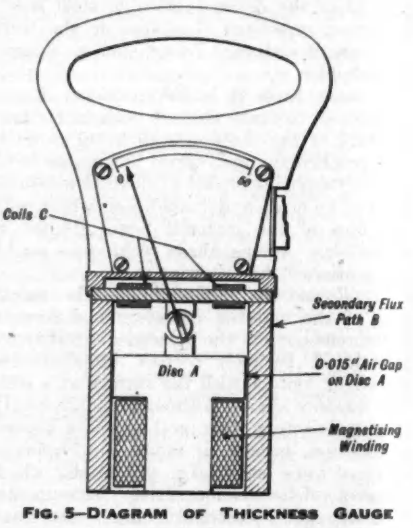


FIG. 5—DIAGRAM OF THICKNESS GAUGE

variation of the moving coil meter movement air gap.

CONSTRUCTIONAL DETAILS OF THE INSTRUMENT

Fig. 7 shows the essential features of the measuring head of the instrument. The main magnetic circuit consists of an outer cylinder and a centre pole of soft iron, the circuit between the pole and the outer annulus being closed by a disc also of soft iron. Between this disc and the outer cylinder an annular magnetic air gap is formed by interposing a ring of brass approximately 0·015in thick. The main excitation winding is 450 turns of 20 S.W.G. enamelled copper wire and is designed to operate at a current of 3·6A. The secondary magnetic circuit, which is shunted across the gap in the main circuit, is arranged as shown in Fig. 7. The moving coil meter movement is inserted in this secondary magnetic circuit so that the flux flowing in it provides the

field for the moving coil. This coil is a standard commercial element designed for use in a milliammeter.

The compensating coil referred to earlier is introduced so as to provide a backing-off magnetomotive force in the secondary magnetic circuit. It consists of about ten turns of 20 S.W.G. wire, the number of turns being adjusted until correct compensation is achieved, in which condition no pointer deflection will occur when the excitation is switched on and off in the absence of a plate.

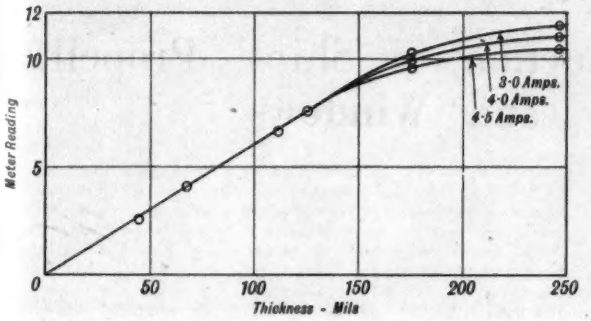


FIG. 6—CALIBRATION CURVES FOR VARIOUS EXCITATION CURRENTS

A switch is fitted in the handle of the instrument to control the excitation current. To take a reading the measuring head of the instrument is placed on the surface to be examined, the control switch pressed and the reading taken direct from the pointer and scale.

The measuring head is connected to the battery and control box by a flexible cable.

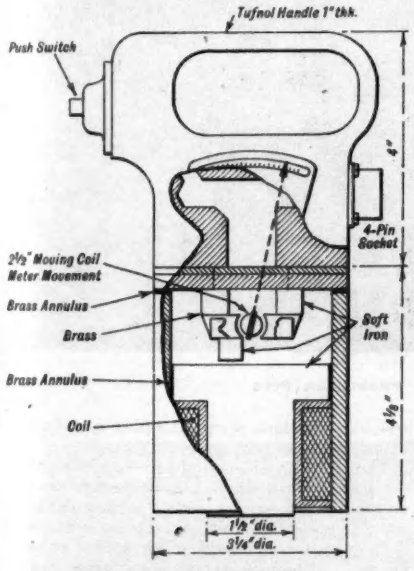


FIG. 7—MEASURING HEAD

The electrical circuit diagram of the control box and measuring head is shown in Fig. 8.

The control rheostat R_2 permits adjustment of the main excitation current to the desired value so that correction can be made for variation in battery voltage according to state of charge. The excitation current is indicated on the check reading ammeter M_1.

The rheostat R_1 and milliammeter M_2 provide control and indication of the moving coil current. This current has to be set to the value required for the particular material of the plate being examined. This adjustment, in effect, enables the same scale calibration to be employed for quite a wide range of saturation flux densities of materials being examined.

The main battery supplying the excitation current consists of seven Nife cells of 10Ah capacity. The control unit is fitted to the battery holder as shown in Fig. 10.

PERFORMANCE OF THE INSTRUMENT

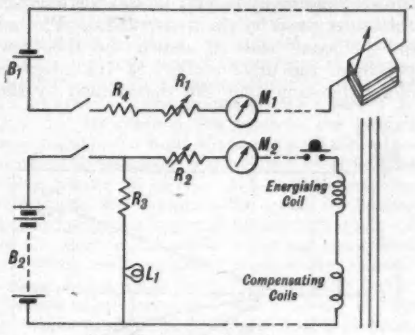
On Normal Machined Surfaces.—The instrument has been calibrated on a number of mild steel test pieces 4in square and ranging in thickness from 0·036in to 0·247in. The calibration curve is shown in Fig. 9.

Overall accuracy over the full range is found to be within 3½ per cent of scale reading or 0·003in, whichever is the greater. This includes reading accuracy, and errors caused by small variations in main excitation current or moving coil current such as might occur while the instrument is in use. Variation of the excitation current in the range 3·55A to 3·65A produces no detectable change in reading. Variation of moving coil current has a large effect on the instrument reading, the effect increasing with increasing thickness of plate measured because of the curved calibration scale. Thus it is necessary to set the moving coil current carefully to the required value before taking readings. The figures for overall accuracy quoted above have been arrived at after making repeated measurements on various samples of mild steels.

The correction in the moving coil current which is necessary to make the standard mild steel calibration curve hold for the low-alloy steels such as low-copper steel, copper-chrome steel, copper-manganese steel and Chromador is found to be less than the accuracy with which the moving coil current can normally be adjusted.

For measurements on metals with saturation flux densities differing widely from mild steel, it is not possible to use the normal instrument calibration curve with only an adjustment of the moving coil current. This also results from the curvature in the calibration curve.

On Rough, Coated or Uneven Surfaces.—The effect of a bad contact between the instrument and the test specimen was first investigated by inserting non-magnetic shims between the instrument measuring head and the mild steel calibration plates. The results are shown in Fig. 11, in which shim thickness is plotted against percentage error in thickness reading for four thicknesses of plate. The curves show that the percentage error increases with increasing plate thickness and that in the worst case an air gap of 0·015in between the instrument and specimen surface produces an error of only about 5 per cent. Thus, reliable measurements can be made on surfaces covered with a coating of paint or rust.



R_1, 50 ohms 1 watt
R_2, 4 ohms 20 watt
R_3, 13 ohms 2 watt
R_4, 100 ohms 1 watt
B_1, Type U2 Dry Cells
B_2, 7 type FA1 Nife Cells
L_1, 6·3V, 0·3A Lamp
M_1, 0–5 mA
M_2, 0–5A

FIG. 8—CIRCUIT DIAGRAM

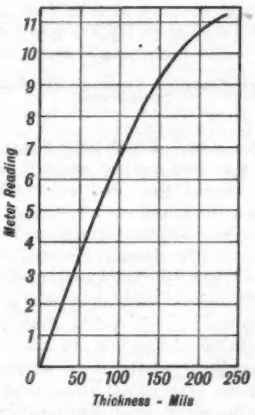


FIG. 9—INSTRUMENT CALIBRATION CURVE

A further series of experiments was carried out on a deeply pitted plate surface to

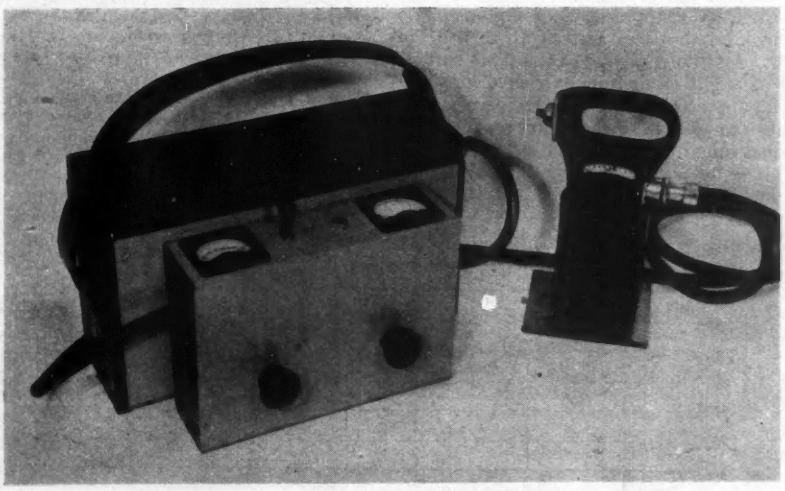


FIG. 10—STEEL PLATE THICKNESS METER

determine the effect of surface profile on instrument reading. A sample plate approximately 14in by 8in and ¼in thick with deep pitting on one face was used. A line profile across the plate was plotted by means of Vernier calipers at intervals of ¼in along the length of the plate. These readings are shown graphically in Fig. 12 and the average thickness given by them is 0·243in. Plotted on the same scale is shown the thickness profile of the plate plotted at 1in intervals along the same line, but determined by the

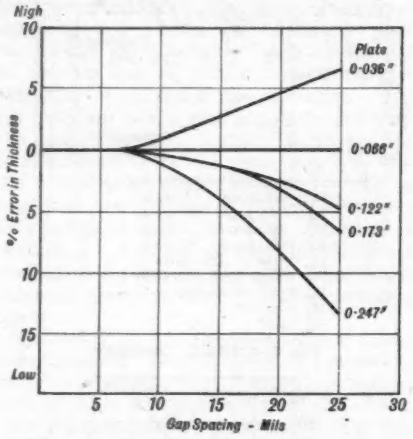


FIG. 11—ERRORS CAUSED BY SURFACE CONDITION

thickness meter. Point-to-point correlation between the two curves cannot readily be obtained since the caliper readings are thicknesses at a point, while the thickness meter readings are integrated over a circular area of about 1¼in diameter, but the specimen does show that the thickness meter reading is less affected by very deep surface pitting. Furthermore, it was noted that there was no detectable difference in the thickness meter reading when measurements were made from corresponding positions on opposite faces of this plate, although the other face was relatively smooth surfaced.

CONCLUSION

The magnetic thickness meter described in this article is suitable for measuring the thickness of carbon and low-alloy steel plates by application to one face of the plate only. The thickness range is 0–0·25in, and the accuracy is 3½ per cent of scale reading or ±0·003in, whichever is the greater. The accuracy of the instrument reading is little impaired by the presence of non-magnetic coatings on the steel surface up to 0·015in thick. Also deep pitting of the plate surface such as might result from extensive corrosion has no appreciable effect on the instrument's ability to measure the thickness of the residual sound metal.

ACKNOWLEDGMENTS

The authors are indebted to Mr. J. D. Watson (now of Anglo-Iranian Oil Company), who carried out most of the early work on the development of the instrument; to Mr. M. W. Thring, Head of the Physics Department, for his advice and encouragement in carrying out the work; to Dr. J. C. Hudson, of B.I.S.R.A. Corrosion Laboratory, who originally suggested the need for the instrument, and to Mr. Hambly and his workshop staff for construction of the instrument.

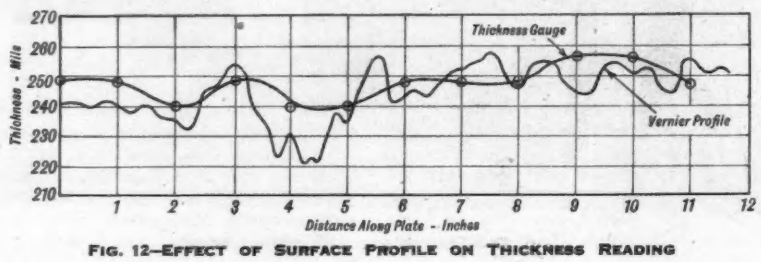


FIG. 12—EFFECT OF SURFACE PROFILE ON THICKNESS READING

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The Production of Ships' Propellers and Windows

DURING a recent visit to Glasgow at the invitation of Bull's Metal and Melloid Company, Ltd., we were able to witness the technique involved in the casting of marine propellers and the machining and other operations necessary to produce the finished article. The company manufacture propellers of "Heliston" design under a licence agreement with J. Stone (Charlton), Ltd., and also ships' windows and sidelights of "Stone" design, while in addition it produces a variety of non-ferrous castings and forgings.

Before making a tour of the works two sets of notes were read which, profusely illustrated by lantern slides, were informative and served to provide sufficient basic information for the better appreciation of the work in progress. Mr. E. F. J. Baugh read a paper on the part played by glass windows in the evolution of the modern ships' superstructure and in strength, symmetry, and æsthetics, and Mr. F. McAlister, the technical director of the company, gave his "Notes on the Development of Bronze Propeller Design with Some General Remarks on their Potentialities for the Future."

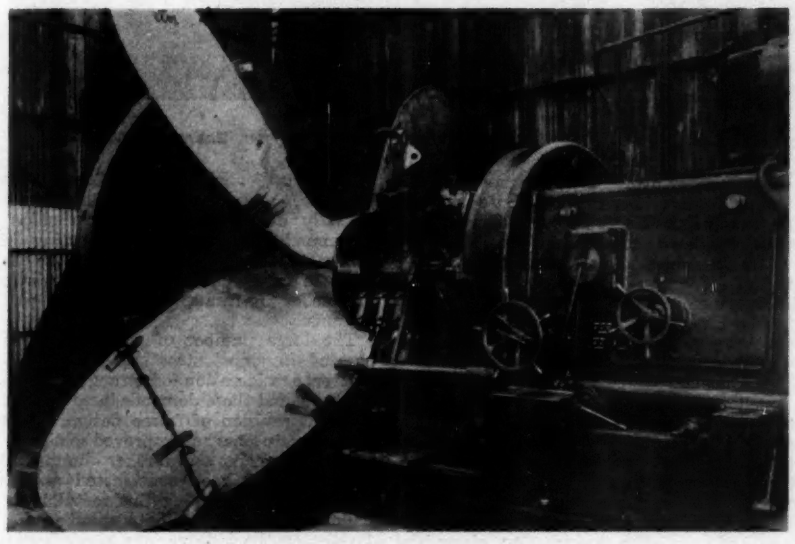
PROPELLERS

In his paper, Mr. McAlister gave some account of the history of the company which was founded by a Norwegian, John Bull, when he started a bronze foundry in London. The success achieved by the propellers made it evident that larger premises were necessary and when Clyde shipbuilders invited Mr. Bull to transfer his business to the North, he established the new works at Yoker in 1901 on the site which the company has continued to occupy to the present day. The original works now houses the foundry, in the present lay-out, which has a capacity of 1000 tons of finished propellers having a maximum weight of 18 tons. Since 1901 additional buildings have been added, and there are now a spacious machine shop, chipping and finishing shops and a pattern shop.

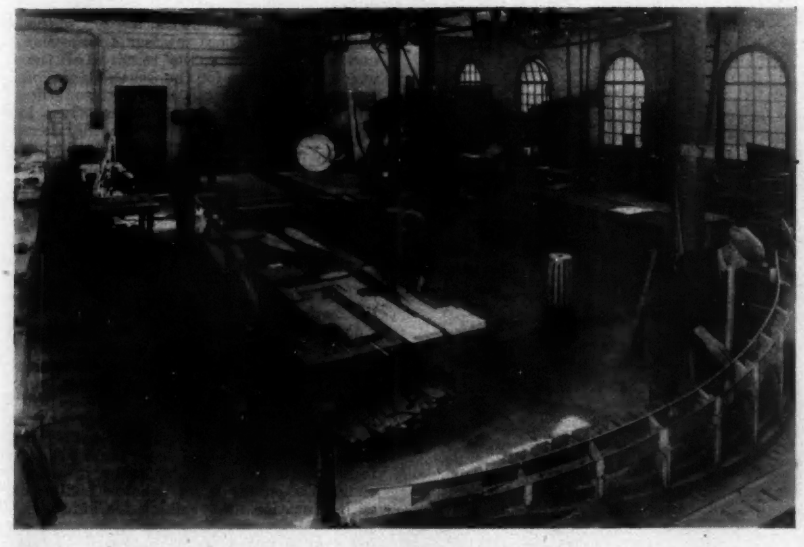
FOUNDRY SHOWING PROPELLER PITS

The foundry, illustrated herewith, is equipped with six pits in which the propellers are cast, and which not only provide a measure of safety for the moulders, but serve to give increased stability to the mould when under pressure. In the immediate vicinity are coal and oil-fired furnaces, each of which can heat some 30 tons of metal to a temperature of 980 deg. Cent., and a number of small melting pots which provide metal for topping up the header. In the machine shop, illustrated opposite, are the machines for carrying out the various operations, and they include a machine by Scriven and Co. for removing the casting head, machining the flange cropping, facing and drilling and other operations required for dealing with loose blades, and a Craven boring and facing machine (illustrated opposite), which crops the casting head, machines the forward and aft faces of the boss, and taper bores the boss to a template, supplied by the shipbuilder, by using a universal joint and eccentric head piece. There is the normal complement of keyway cutting and drilling machines, and also a special pitch grooving rig which uses the pitch rails from which to mark the pitch angle lines on the working face, ready for chipping down to

MACHINE SHOP



BORING AND FACING MACHINE



PATTERN SHOP

the correct blade thickness. The pitch grooving machine serves as a check upon phase and ensures that the track is correct.

There is a battery of pneumatic and electric chipping, grinding and polishing tools in the finishing shops for completing the final operations on the propeller. Carefully trained in the different processes, the workmen attain a high degree of accuracy which has been confirmed by dynamic balancing tests in which propellers, finished by hand in this manner, have been rotated at twice the working revolutions without causing undue vibration or calling for corrections to be made. After chipping down nearly to drawing dimensions, the surfaces are ground and polished to final thickness and the edges checked to template. Grinding is by stone and three grades of discs. When the foregoing operations are complete the pitch is checked and the propeller is given a final polish. Situated in the shop is the static balancing equipment on which each propeller is carefully checked before being passed out as complete. The pattern shop translates the drawing of the propeller into full-size templates and patterns for use in the foundry for building the moulds. Here are built up the heavy wooden striking board, the pitch rails and the light wooden templates which are cut to represent the shape of the blade along radial lines at varying distances from the hub.

In preparation for casting a propeller a heavy iron-spindle is set up at the centre of the pit and around it beds are laid out equal in number to the blades on the propeller to be cast. These beds are bricked up and surfaced with loam. The pitch rail, which can be seen in our photograph of the pattern shop, is set up in position and the face of the loam is swept to a helicoidal surface by swinging a heavy striking board, around the centre spindle, while its outer edge follows the run of the pitch. The operation is repeated for each of the propeller blades, and when the pitch is non-uniform a specially designed articulated striking board is used and it sweeps the blade surface to give the correct pitch at each position without adjustment. On the completed surface the wooden templates, which have been prepared in the pattern shop, are placed at their correct radial distance from the centre and then sprung and pinned in place along a circumferential line. Subsequently, soft sand is packed between the wooden moulds to form a replica of the blade shape and over it is constructed the cope which incorporates suitable reinforcements. After setting, the cope is raised to allow the sand and battens to be removed and is then lowered and rigidly attached to the bed to form the completed mould.

The propeller bronze, (which is an alloy of 57 per cent copper, 40 per cent zinc and 3 per cent consisting of tin, iron, aluminium and manganese), having been raised to the pouring temperature, is tapped into ladles and poured into runner boxes. The metal flows through gates to the bottom of the mould and a casting head is finally added. After cooling, the propeller, which weighs between 56 to 70 per cent more than its final weight, is broken out from the mould and the gates removed before being sent to the shops for finishing. Here the casting header is removed, the boss faces machined to final dimensions, the boss taper bored to take the tail shaft, and the keyway cut. The blades, which are still in the rough condition, are grooved in the pitch rig and forwarded to the finishing shop for chipping, grinding and polishing.

During our visit to the works we witnessed the casting of a propeller for the M.V. "Middlesex," building by Alexander Stephen and Sons, Ltd., for the Federal Steam Navigation Company, Ltd. The propeller, which when finished will have a diameter of 19ft and a finished weight of 17 tons, is shown in our final illustration being lifted from the casting pit.

Each manufacturer has a particular specification and method of ingoting and the alloy used by the company is known as "Bull's Metal," which has a tensile strength of 32 to 34 tons per square inch and an elongation of 20 per cent. During manufacture careful supervision is maintained from the ingoting of the virgin metals to the final testing of test pieces cast

on the propeller. The metal is examined in the furnace and there is a check twenty minutes before tapping. In the laboratory an electrolytic analysis of the metal is made by removing the constituent metals until the copper remains. Microscopic examinations are carried out and the samples are polished by a series of grades of emery cloth, being given a final polish with chromic oxide. The alpha and beta relationship is established, by the intercept method, to ensure that the alpha phase does not exceed a maximum for optimum strength and elongation. Foundry sand is also checked for permeability by measuring the time required to pass a known quantity of air.

In the early days of the company the annual output lay between 200 to 300 tons, and it had risen to 400 tons by 1938. Production during the war amounted to 2000 tons of propellers and some 4000 tons of bronze rods, while in the post-war years 5000 tons of propellers have been delivered, together with over 3000 tons of bronze forgings and castings. Over a number of years there has been an increase in the horsepower transmitted by a single screw, and recent developments in high-speed, single-screw cargo ships and large tankers are having a considerable influence on propeller design. Problems of vibration and erosion are intensified and to satisfy conditions of strength and other factors a propeller to transmit 14,000 h.p. at 100 r.p.m. now weighs about 30 tons. To meet present trends and future demands a new foundry is projected which will be equipped with reverberatory furnaces having a capacity sufficient to meet the quantity of metal required for casting a propeller of 30 tons finished weight. Special mills, storage hoppers and crushers will be included, and the Randupson sand-cement process of mould making will be adopted in order to assist in production and to make for cleaner working conditions. The larger and heavier propellers envisaged suggest that a considerable saving in weight could be effected if propeller alloys of higher tensile strength were available. Such an alloy would permit of thinner blade sections and so help to avoid erosion problems and offer greater efficiency, while the smaller overall weight would reduce the moment of inertia and so contribute towards the solution of shafting problems. The metallurgical problems concerning possible new alloys are the subject of particular study by the company.

In his paper Mr. McAlister related some of the early history of the propeller, discussed propeller design problems, and under ten main headings gave the principal requirements in a bronze propeller. Illustrations gave examples of propellers which had failed and the possible causes were explained.

Windows

As already mentioned, the company are engaged in the manufacture of ships' windows, and Mr. E. F. J. Baugh, in his paper, traced the evolution of the present-day glassed-in structures (as shown in our illustration) from the canvas dodger. Early windows were restricted in size and widely spaced, but over the years much attention has been paid to design until to-day ranges of windows exist which meet every requirement of shipowners and shipbuilders and satisfy Ministry of Transport regulations. Modern liners are floating hotels, and windows, apart from giving a wide range of vision and protection to valuable furnishings, enter into questions of strength and æsthetics.

The company manufacture windows designed by J. Stone and Co., Ltd., and in the paper Mr. Baugh outlined developments from the windows as supplied to the "Mauretania" in 1911 to the frameless window, the "Fusee" and "Broadway" balanced window, illustrated herewith, and the "Flip Flap" window, specially designed for fitting in ships' side accommodation of vessels operating in the tropics. Manufacturing methods have changed and the heavy cast frames are now largely superseded by frames built up from extruded sections.

The large number of windows now incorporated in ships' structures have called for greater consideration of strength and watertightness and these demands have been met by constant revision of frame design, the use of armour plate glass and improved sealing devices. To reduce weight still further aluminium alloy windows have been constructed and experimental sidelights using this metal have been undergoing sea tests for a number of years. To display the wide variety of windows manufactured, the company have established within the works a showroom where the various designs of windows can be seen in their normal setting.

Wheelhouse of the "Port Brisbane"

"Broadway" and "Fusee" Balanced Windows

Propeller for the Motor Vessel "Middlesex"

The Skylon.—At the last meeting of the London County Council there was some discussion during question time about the removal of the skylon, which was erected for the South Bank Exhibition. It was stated that the cost of dismantling would be about £10,000, and of re-erection, including foundation work, about £20,000. Maintenance was estimated at about £1725 a year, of which £1025 would be for floodlighting, if required. No final decision has yet been taken by the L.C.C. on the suggestion that the skylon should be moved to Crystal Palace.

Engineering Training.—A review of the problems of engineering training is given in a monograph entitled *Selection, Training and Education for Technical, Supervisory and Managerial Staffs in the Engineering Industry*, which has just been published by the British Engineers' Association, 32, Victoria Street, London, S.W.1. The booklet includes a special section dealing with those training problems which particularly affect the smaller firms. It is believed that this section will meet a long-felt need, which does not appear previously to have been adequately covered. The appendices include a training schedule for technicians; typical forms for reports and records; an organisation chart of a smaller firm; a list of bodies connected with education and training for industry; and a short bibliography of the important reports impinging on these problems. The price of the monograph is 2s.

A Foundry for an Oil Engine Works

FOR the past eighty years, Crossley Brothers, Ltd., of Openshaw, Manchester, has been engaged in the manufacture of oil engines, and some while ago it decided to embark upon a comprehensive programme of reorganisation and modernisation in order to meet the steadily growing demands for oil engines for marine, land and traction purposes. Part of this scheme involved the extension of the machine shops and the foundry capacity, and for this purpose a new site was acquired near the main works. A new foundry has been built on this site and the space originally occupied by the foundry in the works has been used to extend the machine shops. This new foundry has been laid down to produce castings in a wide variety of sizes, both for Crossley Brothers, Ltd., and for its associate firm, Crossley Premier Engines, Ltd., of Sandiacre, near Nottingham.

The four bays which comprise the main foundry building are 480ft long, three of them being 50ft and one 59ft wide. With the exception of one section, in which the largest castings are made, concrete floors are laid throughout the building. The bays are served by sixteen overhead travelling cranes with capacities varying between 5 and 45 tons, and in the core assembly section a number of 1-ton jib arms are installed. For ventilation twenty rotary ventilators are fitted in the roof, and these, together with fifteen large extractor fans and skylights in the high roof, ensure that a good supply of fresh air is maintained at working level.

Molten metal is supplied by four cupolas arranged in the separate housing shown in one of our illustrations; this building has its own roof and charging platform. A goliath crane which serves the cupolas runs the whole length of the foundry and a 2-ton electric hoist is fitted within the cupola housing itself. Raw materials for the cupolas are stored in a stockyard served by a railway line, arranged at the side of the cupola building, and the pig iron brought to the site by railway wagons is discharged by a magnetic pick-up slung from the goliath crane. In addition to the line serving the stockyard there is a second railway line which delivers material to the end of the core-making bay, and this line, which also passes the end of the dressing shop, is used for the transport of finished castings. A third railway line passing across the middle of the four production bays is used for movement of the large moulding boxes to the stockyard and for the transport of ladles of molten metal between the bays.

The metal supply channels from the cupolas are arranged to discharge into the first bay of the foundry, and much of the alloy used for the special high-duty cast iron produced is melted in an oil-fired Morgan tilting furnace. This alloy is weighed out as required and poured into the large ladles of molten iron at the same time as other ladle additions are made. All metal mixing is under strict laboratory control and accurate weighing ensures that the correct grade of cast iron is produced.

At the cupola end of this first bay a small section has been laid down for the production of small green sand moulds. The sand for the five machines engaged in this work is prepared in an independent sand plant and is taken directly from a storage bin at the end of the railway alongside the cupola house. These machines are fed from overhead hoppers supplied by a conveyor belt above. Moulds from these machines are closed and banked on roller conveyors for filling, after which they are emptied on a mechanical shake-out. From the shake-out the sand returns to the sand plant on an underground conveyor system and the boxes are returned to the machines for re-use.

For the production of medium-sized dry sand moulds one half of the bay has been set aside and equipped with five roll-over, jolting machines, as shown in one of the photographs we reproduce. These machines take moulding boxes up to 3ft long by 3ft wide, and there is also a plain jolter for boxes up to 7ft long by 4ft wide. Facing and backing sand is supplied to the machines from overhead hoppers fed from a large sand preparation plant situated in a building outside the main bays.

MOULDING MACHINES AND MEDIUM CASTING SECTION

In the second bay a large area is set aside for core assembly and for the closing and casting of the large moulds made in the first bay. It also contains pits for casting of cylinder liners, and one end accommodates a knock-out station and the fettling and dressing section of the foundry. Loose and plate pattern moulding is also done in part of this second bay. Four large mould drying stoves serve the first bay and three stoves the second bay; each group of stoves is supplied with dry, hot air from a single firebox.

All large castings for the main engine units are produced in the third bay, and to facilitate their ramming a mobile sandslinger with a radius of 20ft is installed. This machine runs on rails over a length of 250ft in the bay and is served by its own sand preparation plant, which feeds three hoppers supplying sand to the slinger hopper. Most of the work in this section of the foundry is made in moulding boxes, which, when they are cored up and closed, are cast in situ. Two large mould drying stoves are installed and the fettling section has a large shot blasting machine.

Used sand knocked out over floor grids falls on to an underground conveyor arranged across the bays and leading to a sand preparation plant. Here it is cleaned of silt and small coke, and any metal inclusions are removed by a magnetic separator before the sand is deposited in one of two storage hoppers. The cleaned sand has a proportion of new sand and coal dust added to it and, after milling, is discharged by pneumatic control on to a belt and then a bucket elevator which feeds the belt conveyor above the moulding machines. In the first bay, both facing and backing sand is distributed on the same belt, each moulding machine having two hoppers, which are fed by operation of a scraper on the belt to plough the sand off. Considerable quantities of backing sand are used and it is fed from the bottom of its hopper on to a secondary belt, which carries the material forward to the moulding boxes. The secondary belt of the large jolting machine

CUPOLA CHARGING PLATFORM

is fitted to a turntable so that the falling sand can be dropped off as the belt is swung along a moulding box of the maximum size carried by the machine.

The core-making section of the foundry is situated in the fourth bay and has its own sand preparing plant. There are ten bogie drying stoves and a central vertical continuous drying stove for the smaller cores. The core makers are supplied with sand from a pendulum bucket conveyor and the smaller cores are transferred to the vertical oven on a steel band conveyor. Large cores are dried in the bogie stoves, which are arranged in two groups of five units. The cores are delivered to the moulders on petrol-engine-driven trucks.

At the end of the core-making bay is a separate department in which the non-ferrous castings are made. In this section there are four coke-fired Morgan furnaces below ground level. Metal is run directly from the crucibles taken from these furnaces. A wide range of non-ferrous metals is handled in this part of the foundry, including brass, gun-metal, phosphor-bronze, aluminium-bronze, and normal and special grades of aluminium.

Buildings adjacent to one end of the main foundry house an electricity substation, air compressors, and blowers providing blast for the cupolas. A well-equipped apprentice school is used to provide apprentices with a good practical and theoretical background knowledge of the trade before they enter the foundry proper. In an amenities block both washing and bathing facilities are provided for all employees, and in a building separated by the entrance road from the foundry is a large canteen. This building also accommodates a large modern pattern shop and administrative offices for the establishment.

A Range of Germanium Crystal Rectifiers

A WIDE range of germanium crystal rectifiers has been introduced by the Westinghouse Brake and Signal Company, Ltd., 82, York Way, King's Cross, London, N.1. The rectifiers are suitable for detectors, limiters, instruments and general purposes, the self-capacity of each being about 1*pF*. Each rectifier unit is of hermetically sealed ceramic construction and is ½in long by ⅛in diameter. Working voltages up to 100V and forward currents of 50mA are covered by the complete range. Each rectifier is mounted on a colour coded card giving the rating particulars. Details of ratings and types recommended for sixteen specific applications are tabulated in a leaflet (M.R. 14 Suppt. 5) published by the company at the address given above.

Technical Reports

Investigations Into the Structural Use of Aluminium in Ships. By W. Muckle, M.Sc. London: The Aluminium Development Association, 33, Grosvenor Street, W.1. Price 7s. 6d., post free.—This report consists of a summary of investigations which commenced in 1943 and includes work completed in 1950. In the report are accounts of investigations carried out to obtain a theoretical basis for the determination of the scantlings of aluminium alloy structures, to consider the problems due to temperature effects, to estimate the weight saved by the application of aluminium alloys to various ships and to determine the effect of structural weight saving upon the design of ships. Formulæ are given for the determination of scantlings and a table of the particulars of twelve ships, together with detailed results of calculations on the use of aluminium alloys for superstructures and strength decks. There is some account of the compression tests on single and lapped plates and a detailed analysis of the tests carried out on a model superstructure, including stress distribution, longitudinal strain, load deflection curves under loading conditions producing uniform bending moment and maximum bending moment at the centre of length. Conclusions based on the investigations are recorded and an appendix lists the chemical and physical properties of the aluminium alloys for shipbuilding purposes, together with the standard nomenclature.

Post-War Developments in Operational Research*

A. W. SWAN, B.A.Sc., A.M.I.Mech.E.

INTRODUCTION

DURING the war, operational research in Great Britain in the Navy, Army and Air Force was carried out by scientists, who were physicists, chemists, mathematicians and others. Their solutions to problems, which were notably successful, were often based on highly intricate mathematical procedures.

At the same time, but quite independently, there was a considerable development, mostly under the auspices of the Ministries of Supply and Production, of the use of statistical quality control and statistical sampling, single, double and sequential. This work was carried out partly by mathematical statisticians and partly by engineers.

The development of operational research since the war has been influenced by both fields of activity. Quality control and statistical sampling suffered from 1946 onwards a serious setback in Great Britain, and there has in that country been nothing like the development in this field which has been shown in the U.S.A. and has led, among other moves, to the successful flotation of the A.S.Q.C. In passing, it has been interesting to observe the slow, but steady, improvement in the *A.S.Q.C. Journal*, from one which was ultra-elementary and largely repetitive, to one which, while still catering mainly for the practical man who is a beginner in statistics, now contains in each number useful papers of a more advanced kind.

While quality control as such is not now of much importance in Great Britain, the application of statistical methods to industrial problems of great variety is increasing rapidly and forms an important branch of operational research to-day. The wartime scientists who are still in the field of operational research consider that applied statistics is a rather narrow interpretation for operational research, and this may be true. The fact is that the operator is bound to be affected by his background and definitions of operational research vary accordingly. The chemist or physicist tends to consider an industrial problem as parallel perhaps to some crystalline structure; an individual in an organisation may strike him as being a catalyst, and so on. The writer, being primarily an engineer, tends to turn to thoughts of time and motion study, to resort to graphs of various types and to design special slide rules and nomographs.

Some British scientists consider that operational research ceases as soon as it leads to routine procedure. The writer's own view is that the essentially new feature of operational research which distinguishes it from, say, scientific management as set out thirty years ago by Taylor, Gantt and Gilbreth is the use of present-day statistical methods. The concensus of British opinion provides the working basis that operational research is the application of scientific thinking to industrial problems leading always to executive decision.

An important point, not made to date as far as one knows in the literature, was put to the writer recently by Mr. Kenyon and Mr. Ashpole, of the textile division of Courtaulds, Ltd. It is that present-day methods provide a complete kit of tools for research, since while quality control, statistical sampling, statistical examination of time study results, costs, &c., provide material for research by examining present conditions, and suggest policies for improvement, the planned experiment of the Fisher type, by using hitherto untried conditions, may also be used to look directly into the future. In the textile field, for instance, the effect of new components in the sizing mixture may be tested. This readily links up with a point stressed by Brownlee in *Industrial Experimentation*, that one of the main advantages of the statistically planned experiment where a large number of factors may operate simultaneously over the "remove as many factors as possible or bit by bit" type, is that apart from the practical difficulties in industry of examining factors one at a time, if one succeeds in a laboratory in removing most of the factors in a complex position, one can very easily have conditions which have little similarity to the ordinary works conditions and the conclusions arrived at may be misleading. There is, furthermore, the matter of interactions. One might take as a simple example of a condition which involves interactions the examination of temperatures in a billet heating furnace. It may be that, overall, the temperature is higher at the intake than the output end, but that at the intake end it is higher on the right side than on the left, whereas at the output end conditions are reversed. Statistical methods provide the only way of finding out whether such interactions exist and, if they exist, of assessing their importance. Another advantage of the statistically planned experiment, also made by Brownlee, is that one operates it usually on two or three "levels" of, say, steam pressure, &c., whereas in the "bit by bit" experiment one has to select a single level and may well select the wrong one and again have results that are misleading. It is worth mentioning that those who are experimenting with statistical tools and are a little afraid of analysis of variance, sometimes test a set of means in pairs by the "*t*" test. By not using the full technique of analysis of variance they lose information on interactions which may be of considerable industrial importance.

A definition which has some bearing on whether the use of quality control charts can be correctly considered as operational research is the term "in control" commonly used in connection with "average-range" charts. "In control" usually implies that measurements from the operation under discussion would conform to a normal distribution, whereas "in control" should be more accurately described as "stable." On the same mid-point, one can have any number of normal distributions varying infinitely in width, and industrially an operation is not in control, be it ever so stable, unless the base of the distribution for the population is narrower than the tolerances to which the operation is supposed to conform. This view is implicit in the justifiable pride which users of "average-range" quality control charts show in a gradual narrowing over a period of time of the limits for average and a lowering of the limits for range, both of which developments imply a reduction in the overall variability of the process with a corresponding reduction in the width of the base of the distributions. When quality control charts are used in this way as pointers to better practice rather than as merely static indicators that conditions are no worse than they were, there is justification for the view that they are being used as operational research.

In connection with the above ideas, one wonders if the word "random" is sometimes rather overworked, and if industrially it may tend to be a word which helps one to escape from an awkward position. "Assignable causes" tend also to be causes beyond those which we accept as unfindable, but which, fortunately for us, behave in a stable manner and give us a nice cosy normal distribution.

THE GROWTH AND ACTIVITIES OF AN OPERATIONAL RESEARCH DEPARTMENT

At the close of the war the writer approached the United Steel Companies, with whom he had been before the war on other work, suggesting the setting up of a new department which would apply statistical thinking to management problems. The title Quality Control Department was inappropriate as it was hoped to tackle problems in output, costs, &c., and the name selected was the simple one of Statistical Section.

The section was started and continued with a small staff, consisting of the writer, two statisticians, two girl computers, a typist-secretary and a junior girl clerk, and at this point it may be of interest to set down the writer's firm views about the selection of senior

* Lecture on "Some Post-War Developments in Operational Research in Great Britain" delivered at Cleveland, Ohio. November 8th.

staff for this class of work in an industrial organisation. Requirements are (1) a pleasant, firm and tolerant personality; (2) a sense of humour; (3) a degree in physics, chemistry, metallurgy, engineering or mathematics. A knowledge of statistics is not essential, but the mathematical background to learn statistics is a *sine qua non*.

The importance of personality cannot be exaggerated. The operational research worker must be able to win and keep not only the confidence of the "practical" men with whom he has to deal, but their personal friendship. A small slip in psychology may wreck a complete programme as is illustrated by one which was corrected in time and led to the happiest results.

The first job the United Steel statistical section did was an investigation into whether sampling could be substituted for 100 per cent inspection of the dimensions of hot rolled bar. The work was carried out with the result that sampling was shown to be possible leading to important savings in cost. When the draft report was ready the writer sent it to the mill manager and chief inspector for consideration before issue, a standard practice, and sensed from telephone conversations that something was wrong. A visit revealed that the manager and inspector felt aggrieved because no mention had been made of their earlier attempts at statistical solution of the same problem, attempts which had not been successful. The allusion was put in with the best of goodwill, the report went through; the scheme was established with such success in the saving of "brass" and the speeding up of delivery that the branch concerned proceeded to form its own statistical section to work in conjunction with the central statistical section.

It will be noticed that a technical university degree which involves a fair amount of mathematical knowledge is considered to be essential, but that a lack of prior knowledge of statistics is not a bar. The writer has engaged and found equally successful chemists, physicists, electrical and mechanical engineers and mathematicians. Two at least had no previous knowledge of statistics.

The writer has incurred the wrath of certain ladies by insisting that the senior staff at least in a steel works must be men. One of the girl computers had ambitions and the necessary knowledge to be a statistician, but when the writer took her to discussions in the works offices with Siemens' managers and the like, they complained privately afterwards that they had felt unable to use certain words which they would have used in ordinary conversation with the writer and that this had put them off their stroke! Chivalry has its disadvantages, it appears.

Equipment eventually included three electric calculating machines. One of the greatest advantages of the fully automatic calculating machine in statistical calculations is its adaptability to the summing of squares, particularly the simultaneous summing of squares for Y and X in a regression calculation giving $SX^2+S2XY+SY^2$ in one set of operations. This sort of work formed a considerable proportion of the calculating side of the statistical section, and it was put on a standard basis by using the Doolittle method, which had been noticed in various American textbooks. One of the advantages of this method is the provision of check sums which, if incorrect, show errors at an early stage in the work. This feature proved to be particularly valuable when use began to be made, as it was eventually, on a considerable scale of the Hollerith punched card equipment. The British Hollerith machines differ in some respects from those of the parent, I.B.M., but the method of use is essentially the same. While the computers were highly skilled and could be asked simply to do a Doolittle or an analysis of variance, &c., on data provided, it was always assumed that the Hollerith operators knew nothing of mathematical theory and instructions for them was on a strictly mechanical basis.

Tribute, by the way, should be paid to the development of the Hollerith technique for statistical purposes by the Mathematical Division of the National Physical Laboratory.

Origins of Jobs

The general method adopted in what was originally a pleasantly sceptical atmosphere, in which the pleasantness remained and the scepticism disappeared, was to take a pilot job, bring it to what was hoped would be a successful result, and go on from there. The idea was always to help rather than to correct, and the preferred origin has always been a request for help rather than a suggestion from statistical section that such and such work should be undertaken. To help to know the kind of job on which help could be given there was a continual insistence in conversation with managers on the following fundamental points in statistical thinking:—

(1) Statistical methods allow one to estimate within defined degrees of risk the properties of a large number of results (weights, outputs, &c.) from a sample of those results. They are therefore economical since they tell how few results to use.

(2) From a complex position statistical methods can sort out the order of importance of the factors and show the proportion of the answer given by the existing information. In one case all the known existing factors only accounted for 20 per cent of the total variability, which caused the committee concerned to think furiously and search for new factors.

(3) The statistical answer to a specific query is usually "yes" or "not proven." If it is "not proven" this may be either because, although the effect examined exists, the data provided are insufficient to prove it and additional data, specified in amount, are required to give a definite answer, or because the effect can be neglected.

These points were also made occasionally in lectures to managers, but one had to be prepared for some leg-pulling. ("Why are you sitting at the back, George?" "I can't hear you so well back here.")

Gradually, a large number of people came to realise the kind of help that the statistical section and the corresponding sections at the branches could give; there were always requests and these continually widened in variety. One can call to mind without difficulty such a varied assessment as the following:—

(1) Provide an index of blast-furnace performance to give a more faithful picture than "coke per ton of iron."

(2) Investigate varying percentages of people leaving different departments.

(3) Work out a sampling scheme for refractory brick.

(4) Improve sand control in the ingot-mould foundry.

(5) Investigate the possibilities of using sampling methods for maintenance costs instead of exact accounting methods.

The report on the index of blast-furnace performance illustrates a point which the writer considers of importance. It was an instruction that all reports, except those of a research character, such as those dealing with points of theory, must contain recommendations. When the draft of the report on the blast-furnace index was completed, the writer noticed that there were no recommendations. On inquiry the assistant concerned said that he knew too little about blast-furnaces to make recommendations. "You believe that your index is better than coke per ton, don't you, and that it will give a much more faithful picture of events?" "Yes." "You want them to use the index, don't you? That is your recommendation; put it in." The index was used and has been such a success that it has formed the subject of a paper by the works manager of the branch concerned to the Institute of Fuel, with full acknowledgment of the benefits received and their source.

It may be added that all reports by statistical section begin with "Object, Results, Recommendations," and all are written in plain English with the smallest possible use of special statistical terms. The writer has always recommended that these reports should be written bearing in mind the personality of the individual to whom they will be mainly addressed, usually a branch works manager or a departmental manager. It was suggested in the case of one rather obdurate individual that a particular report should be written in Braille, but this was probably an ill-natured remark.

Investigation into Rail Defectives

It may be of interest to set out in detail the steps taken in the progress of an actual job.

Although statistical methods have provided the principal tools in the operational research kit, the problems were never statistical problems as such. In this case, the problem was set in conversation by the works manager of the branch, somewhat as follows:—"Our percentage of rail defectives is higher than we like, will you please look into the matter and make recommendations?"

The first step, a standard one with the writer, was to spend some time at the branch cross-examining the steelworks manager, the Bessemer manager, the head of the works office, the rail bank manager, and many others, securing their views on the position. The writer also did some intensive technical re-study of the Bessemer process and the rolling of rails. This procedure, by the way, although he did not know it at the time, is in accord with the recommendations by Killeffer in that admirable book *The Genius of Industrial Research*. Killeffer believes that it is the first duty in any research to collect, collate and digest information from every possible source.

All this information was reduced to a sheet of foolscap on which were written all the subjects which had been measured at one point or another in the manufacture of Bessemer rails, plus observations on identification of ingots and rails, an important and sometimes difficult matter in hot rolling, and on works information. There then followed another talk with the works manager which was followed in turn by a meeting between the heads of departments, the works manager and the writer and his assistant.

The writer's observations at the meeting were roughly as follows:—"You measure everything that everyone else does except the temperatures in the vessel (Bessemer converter), in the ladle and at rolling. Do you think these temperatures matter and, if so, should they be measured? Identification of ingots through to rolling is good; it is possible to tell that a certain ingot is, say, No. 10 in a particular cast. Identification of finished rails by hot stamping needs improvement. Your works information is good and conscientiously kept, but awkward from our point of view. A single cast history sheet would be more useful."

The response to these comments was: "We realise we should measure the temperatures you mention, but the difficulties of measuring temperatures in an acid Bessemer converter are very severe. However, we will try. We realise well enough that our method of hot stamping identification of rails needs improvement and we will take that on. As to the cast history sheet, will you design it for us?"

The first parts of these undertakings were promptly carried out. The cast history sheet was worked out by the head of the branch steel control, the writer's assistant and the writer—a compact document made as simple as possible and coded so that the information could be readily transferred to Hollerith cards.

The writer then retired from the scene, leaving an extremely difficult multiple factor analysis using works data on the new history sheet to be carried out by his assistant. This analysis, which involved eighty factors, was carried to a successful conclusion, the important feature of the results being to point out the order of importance of the factors so that first things should be tackled first. It was found, for instance, that the main place for attention was the teeming of hot steel from the Bessemer ladle into the ingot, and that while there was no significant "time of day" effect, e.g., night was no better or worse than day, there was a significant shift effect, one gang of men was definitely better than the other two gangs.

This job, which was carried out three years ago, has had a remarkable sequel. About a year ago the branch became worried about

a particular rail defect and asked for a special inquiry. This was carried out using a slightly modified cast history sheet. This time the result showed that out of the eighty odd variables, three only mattered to an important extent. This answer proved at first to be too simple for the branch, and it was not believed (cf. 2 Kings 5, 10–14). As, however, further data gave exactly the same result, it was eventually heeded, the three factors which it was suggested should be reduced were held to the minimum practicable, the percentage of the particular defect was halved, and congratulatory letters are now being written.

The above job illustrates various aspects of operational research work as carried out by the statistical section. (1) The job was the result of requests from the people who wanted help; (2) there was completely co-operative effort within the section and between the section and the branch staff; (3) there was little correspondence and telephoning, points for discussion being dealt with in personal talks at the branch, not in the statistical section's office in Sheffield; (4) the job began with a careful and exhaustive inquiry into technical and other conditions; (5) the inquiry led up to a statistical analysis of an advanced kind; (6) the results were typical of many such inquiries in that some factors were shown to be of extreme importance, others of little importance, and quite a number as non-significant; (7) the results led to valuable concentration of effort leading to substantial improvements.

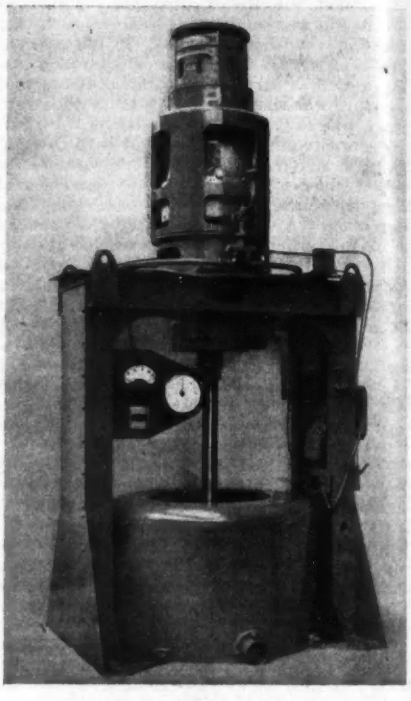
Vertical Duplex Fluid Coupling

FOR transmitting powers, ranging from fractional to several thousands, from the prime mover to a variety of machines, the "Fluidrive" system has been widely employed. Recently, the Fluidrive Engineering Company, Ltd., Isleworth, has applied the system to a high-duty sugar centrifugal for which a "Duplex" fluid coupling for high-speed acceleration and rapid fluid braking has been adopted in association with a continuously running motor.

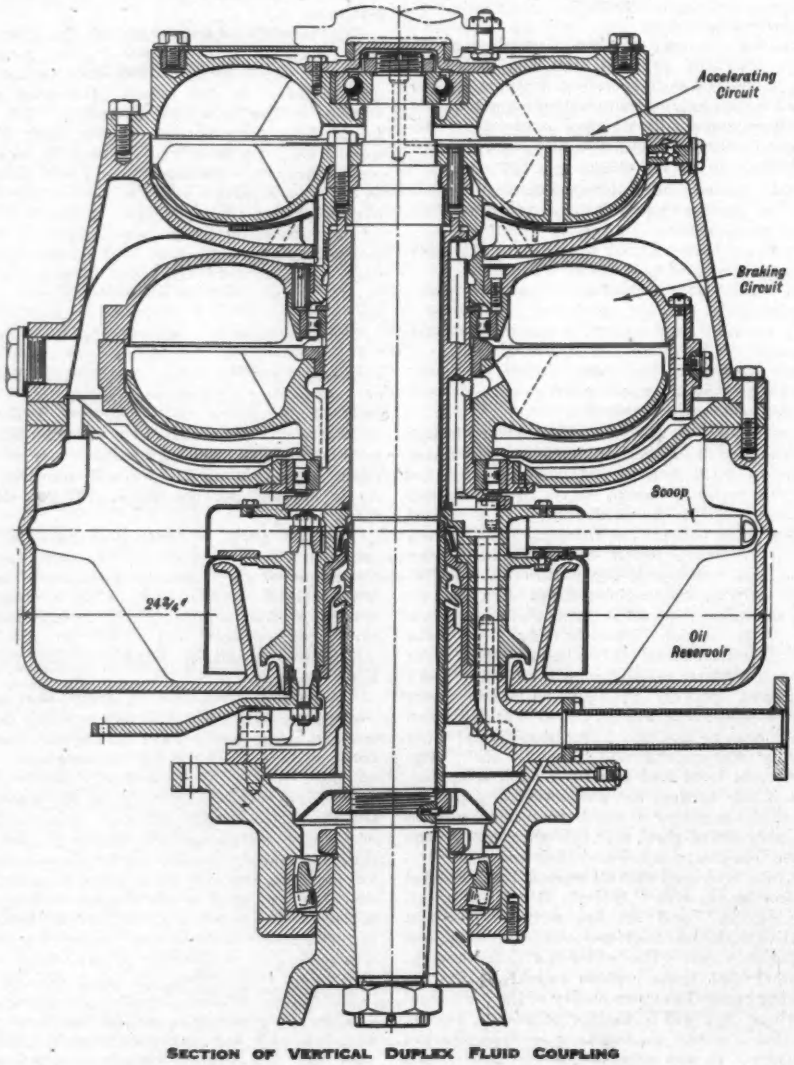
The basket of the centrifugal machine is rapidly accelerated to a designed speed, and, after the appropriate full-speed run, is rapidly retarded ready to begin ploughing; the requisite low speed then being maintained while the sugar crystals are ploughed out. Retardation by use of the more usual friction brake resulted in the rapid wear of brake linings and the need for constant replacements.

This problem of a quick acceleration and quick reduction of speed has been solved by employing a variable-speed "Duplex" fluid coupling incorporating Vulcan-Sinclair scoop control and driven by a continuously running squirrel-cage electrical motor. Our illustration shows the sugar centrifugal and "Fluidrive."

The variable-speed vertical "Duplex" fluid coupling embodies two separate circuits, one for acceleration and the other for braking, also a rotating reservoir chamber which contains the hydraulic medium. Fitted within the sump is a retractable sliding scoop by which oil is fed through a tubular cooler to one circuit or the other, as controlled by the diverter valve. The squirrel-cage driving motor can be started and run up to full speed against virtually no load by a star delta starter, or a direct switch, and the general arrangement of the fluid drive is shown in the drawing. In the accelerating circuit the impeller, held within a shroud fixed to the outer casing and reservoir casing, is driven by the squirrel-cage motor through a diaphragm plate and, acting as a centrifugal pump, transmits power to the runner through the medium of the vortex ring of oil circulating in the working circuit. The runner serves as an oil turbine and drives the output shaft, mounted on a hub carrying the braking impeller bolted to an inner casing. The lower portion of the braking circuit acts as a stator



SUGAR CENTRIFUGAL AND FLUID COUPLING



SECTION OF VERTICAL DUPLEX FLUID COUPLING

and is keyed to the scoop tube housing, which is attached in turn to the scoop housing bracket and bearing housing. When the oil is diverted to the braking circuit kinetic energy is absorbed and the shaft speed reduced.

With the unit at rest the operation sequences on the demonstration machine are as follows:—The scoop is moved to the "out" position and the 25 h.p. motor started and left running. Then, after the diverter valve has been opened to the acceleration circuit, the scoop is changed to the "in" position by means of its control lever. The basket of the sugar centrifugal accelerates to maximum speed, at the desired rate of 970 r.p.m. in thirty seconds, and the diverter valve is switched over so that the oil enters the braking circuit and speed is reduced to about 300 r.p.m. in fifteen seconds, and then further reduced by mechanical braking. At this point, for the ploughing operation, the diverter valve is changed to direct the oil to the acceleration circuit while the scoop is moved to the three-quarter "in" position to give a ploughing duty at 180 tons-feet torque at between 50 to 70 r.p.m. A mechanical brake actuated by a "Thrustor" is automatically applied and released so that the required speed range is maintained. The "Thrustor" is energised by means of a contact switch which, in turn, is controlled to "on" and "off" positions by an Igranic dynamic relay driven from the basket spindle and set to operate "on" at 50 r.p.m. and "off" at 70 r.p.m. When the ploughing operation is completed, the scoop is moved to the fully "in" position in order to bring the basket up to the full speed and, as the machine picks up speed, the basket is charged with massecuite.

The demonstration machine seen in our

photograph is a 42in by 20in Pott Cassels and Williamson unit, with a basket inertia of 2000 lb-ft² and is driven by a 25 h.p. motor which takes twice full load current, 60A, during the acceleration period. The actual coupling has been built for a machine with a basket inertia of 6000 lb-ft² when empty, and 8000 lb-ft² when full of sugar, and in service the duty of the coupling is to accelerate the basket to 1200 r.p.m. in sixty seconds and retard to ploughing speed in thirty seconds. The braking circuit is used for fifteen seconds to reduce the speed to 400 r.p.m., whereupon a mechanical brake is brought into action for fifteen seconds to stop the basket. Hence, the mechanical brake only has to dissipate one-ninth of the kinetic energy of the basket at full speed.

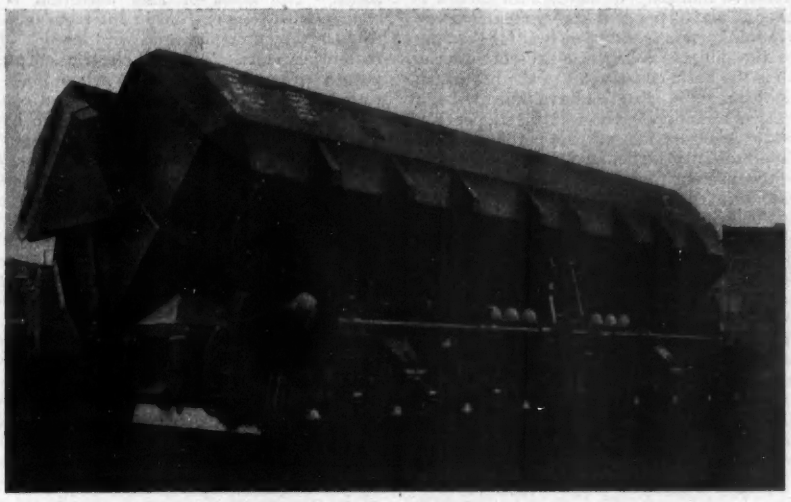
The sugar centrifugal shown in our photograph is usually operated in batteries, and behind each machine is placed a distributing mixer. When the centrifugal is started a valve gate in the mixer is opened, and a mixture of syrup and sugar, known as massecuite, pours into the basket, which is accelerated to the maximum speed. This speed is maintained until the syrup is thrown off, and the dry sugar is left behind; then the operator reduces the speed by switching over from the accelerating circuit to the braking circuit of the fluid drive. When the machine is almost at rest, a cast iron plough blade is introduced and the ploughing operation is commenced, the machine being accelerated to between 50 and 70 r.p.m., and maintained at this speed until the sugar has been ploughed out through the bottom of the basket.

148-Ton Self-Tipping Railway Wagon

In the development of the brown-coal deposits of the Rhineland, in the English Zone, attention has recently been paid to the working of the deeper seams. In these operations a very thick overburden has to be removed, for which special transport means had to be designed and constructed. It was found to be particularly desirable that a wagon should be available which could be very quickly loaded and emptied. The order for this wagon was placed with the Friedrich Krupp Locomotivfabrik of Essen, a firm which has completed and tested an entirely new design of self-tipping railway wagon, having the following general dimensions.

Maximum length over buffers	13·69 metres
Overall breadth	3·4 metres
Maximum height	3·875 metres
Designed cubic capacity	74 cubic metres
Carrying capacity	148 metric tons
Weight of wagon	52 metric tons

The capacity is some seven times that of the normal goods wagon of the German State Railways, while the axle loading is about 25 tons. There are eight axles arranged in two pairs of four. They are clearly to be seen in the accompanying two illustrations, which show the wagon in the upright and tipped positions, respectively. The design is such that owing to the eccentric loading the tipping operation is fully automatic, as soon as the retaining bolts and locking mechanism has been released. In the final position the total tilt is 51 deg. In the operation one side of the wagon is raised to a high position as shown in the photograph, so that the potential energy for the return motion is stored up. In the tipped position the wagon-tipping mechanism automatically locks itself.



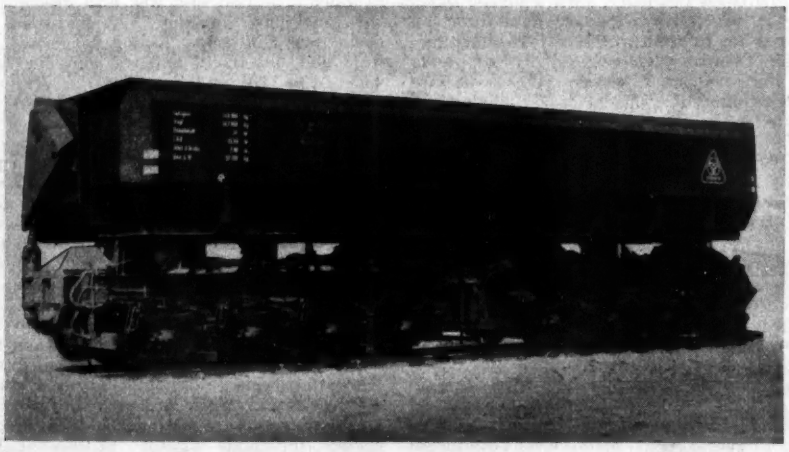
WAGON IN TIPPED POSITION

When the mechanism is released an operation usually performed by an attendant, the wagon automatically returns to the normal position. The whole discharging operation takes place in a few seconds. To deal with possible unfavourable and one-sided loading conditions and bad tracks, an auxiliary compressed-air tipping arrangement has been added. This makes possible the working of the tipping and locking mechanisms by means of compressed air. The dimensions of the air cylinders, which are clearly shown in our illustrations, are so arranged that the empty wagon can be put into the tipped position by compressed air and the same means can be used to assist the tipping and locking motions.

The wagon is designed for the narrow curves and uneven track conditions associated with open-cast mining operations. All the axles are fitted with brake gear, which is designed to give a braking effort of 70 per cent of the empty wagon load and 45 per cent of the loaded wagon. Even on heavy gradients the wagon can be quite safely operated.

The usual maximum dimensions for railwey wagons have been exceeded in order to give the largest possible capacity per running metre of train length. The wagon can be safely run over the normal German railway system, even if the neighbouring track is occupied or is closed.

The Friedrich Krupp Locomotivfabrik is represented in this country by the firm of J. M. J. Maus Ltd., of 35, New Broad Street, London, E.C.2.



WAGON IN RUNNING CONDITION

American Engineering News

(By our American Correspondent)

Preservation of Documents at the Library of Congress

Both the original parchment documents of the Declaration of Independence and the Constitution of the United States have now been placed in sealed glass enclosures as a result of a joint project undertaken by the Library of Congress, the National Bureau of Standards, and the Libbey-Owens-Ford Glass Company. In accordance with the recommendations of the Bureau, the four leaves and the letter of transmittal of the Constitution and the leaf of the Declaration of Independence have been sealed in airtight envelopes, each envelope consisting of two panes of glass bonded to a metal frame. Each document leaf has its own enclosure and rests upon special pure cellulose backing paper in an inert atmosphere of 99·99 per cent pure helium having a controlled humidity. The enclosures are being exhibited in the shrine at the Library of Congress behind special filters which shield the parchments from destructive light rays.

Theoretically, a perfect vacuum would appear to provide the ideal environment for the parchments, but even a partial vacuum is difficult to maintain for any protracted period. A vacuum would also create a mechanical problem, for the enclosure and the bond would be subject to considerable stress. An inert gas was selected for the preservation of the documents primarily because such a gas is not chemically active and therefore will not enter into chemical reaction with the parchment or ink, as would oxygen. Moreover, an inert gas does not support life, and will protect the documents against insects and other living organisms. Of the inert gases available, helium was selected, as it is available from the U.S. Bureau of Mines in a very pure state and free of oxygen. Its relatively high thermal conductivity compared with air makes it easy to detect the leakage of air into an enclosure.

The presence of large amounts of moisture is known to lead to deterioration of documents by causing a loss in strength of the parchment or paper. Such materials in humid atmospheres are subjected to the danger of attack by micro-organisms that do not require air, but that do require high moisture environments. On the other hand, too little moisture leads to brittleness and cracking, and eventually to a breaking up of the parchment. Research indicated that

the relative humidity of the helium should be between 25 and 35 per cent at room temperature. This humidity was found to be best for the long-range durability of collagen, a protein material, which is the basic constituent of the parchment of the documents. Studies have indicated that a relative humidity greater than 85 per cent leads to deterioration of the parchment. A relative humidity less than 25 per cent dehydrates the protein molecules of the parchment, causing brittleness and cracking.

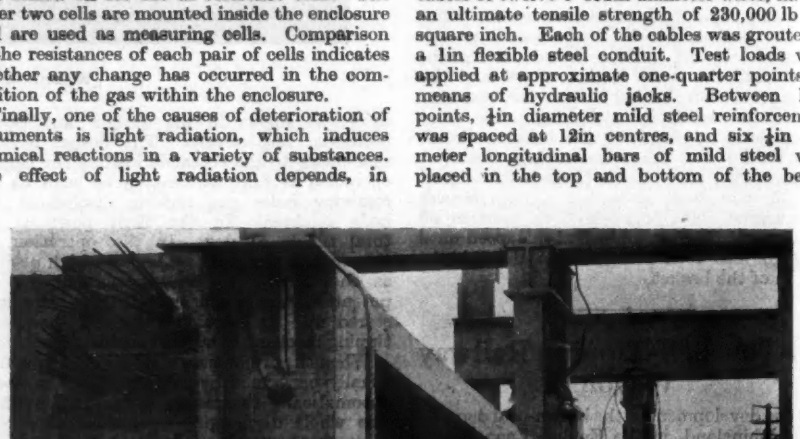
Two considerations determined the selection of the glass enclosures: first, the need for glass plates that would as uniformly transparent and secondly, the need for an enclosure whose components could be assembled and sealed into an air-tight structure without damaging the documents. Here the principal consideration was the effect of heat on the documents. Any process which involves the sealing of materials within an air-tight enclosure requires the use of heat at some stage in the operation. It was thus necessary to select a process which required a minimum of heat and which precluded the transference of a possibly harmful amount of heat to the documents. The National Bureau of Standards determined that double-glazed panels made commercially as insulating windows would meet these requirements. The Libbey-Owens-Ford Glass Company agreed to co-operate in the project by preparing "Thermopane" enclosures for the documents. The enclosures consist of two rectangular panes of tempered plate glass, approximately 30in by 25in by ¼in thick each, separated by ⅜in by a $\frac{1}{16}$in thick lead strip, which is set in approximately ¾in from the edges of the glass panes and which completely encircles the enclosure. The two panes of glass have a special metallic coating applied at places where they make contact with the lead strip. This coating makes it possible to bond the lead strip to the glass panes by solder, thus completely sealing the interior cavity from the outside atmosphere. A bronze bracket, $\frac{1}{16}$in wide, is inserted inside the enclosure to frame the document completely and to hold in place the glass cover plate, which rests on the document to keep it flat. A trial sealing of a facsimile of the Declaration of Independence in such a glass enclosure was conducted at the Bureau in June, 1950. This test provided information on the detailed steps in the sealing process and on the performance of equipment needed for the original documents. Following the trial sealing, tests confirmed the air-tightness of the enclosure.

The difficulty in retaining the properly humidified helium intact within the enclosure and in excluding atmospheric gases is two-fold. Any handling of the enclosures or changes in temperature may cause stresses in the bonding components between the two glass plates of the enclosure. There is some chance that such stressing might produce minute openings in the bond. Moreover, matter, in spite of its apparent imperviousness to change, is dynamic in nature by virtue of its atomic structure. Thus, in the course of time, there are possible changes in the constitution of the bond—particularly those changes resulting from seasonal temperature variations—which can lead to minute openings. If the presence of such openings is known it is a relatively simple matter to find and reseal the openings long before any harmful change in the helium content of the enclosure occurs. Hence, the problem was to provide a suitable detector. The National Bureau of Standards selected a thermal-conductivity gas analyser as the leak detector. This detector is based upon the fact that each gas is distinctive in its ability to transfer heat, so that any change in the composition of a gas can be observed by measuring the change in its thermal conductivity. The equipment which has been developed is small enough to let the detector be built permanently into the enclosure and it is simple enough to let observations be made either continuously or as frequently as desired without removing the enclosure from its shrine at the Library of Congress. The leak detector consists of measuring cells, which are sealed within the enclosure, and of certain components comprising the external leak detector instrument. The basis of leak detection is the change with temperature in the resistance of a 0·001in diameter platinum wire in each of the measuring cells. Thus, if electric current is passed through such a wire when it is surrounded by gas having a low thermal conductivity, the heat generated in the wire by the current cannot readily escape by transfer to that gas. This leads to a rise in temperature of the wire and its resistance becomes correspondingly higher. If the instrument is set to read zero in an atmosphere of pure helium, leakage of air into the helium atmosphere will be detected by the increase in the resistance of platinum wire. For each enclosure four thermal conductivity cells are involved. Two of these are sealed within each enclosure; two are situated in the channel along the edge of the enclosure. The four cells in each enclosure are connected to form the equal arms of a Wheatstone bridge. Two of the cells, in opposite arms of the bridge, are filled with helium and sealed off for use as reference cells. The other two cells are mounted inside the enclosure and are used as measuring cells. Comparison of the resistances of each pair of cells indicates whether any change has occurred in the composition of the gas within the enclosure.

Finally, one of the causes of deterioration of documents is light radiation, which induces chemical reactions in a variety of substances. The effect of light radiation depends, in general, upon the kind of radiation and the nature of the substance involved. Studies at the National Bureau of Standards revealed that damage to documents like the Declaration of Independence and the Constitution is caused largely by ultra-violet light and by visible blue and violet light. Radiant energy from incandescent-filament lamps and from diffused daylight is incident on the cases at the present site of the shrine, although no direct sunlight strikes the cases. There has now been installed in the cover door of each case of the shrine a laminated glass prepared by the American Window Glass Company, with a plastic interlayer in which the necessary light-absorbing material has been incorporated. The Eastman Kodak Company co-operated by supplying the necessary large yellow cellulose acetate sheet required for this project. The yellow acetate sheet is similar in optical properties to a "Wratten 4" filter and absorbs completely in the range from 310 to 430 millimicrons. Both sides of the filter were coated with polyvinyl butyral to facilitate lamination with glass.

Tests of Prestressed Concrete Beams

More than a year of research into the potentialities of prestressed concrete construction as applied to large industrial buildings has been done by the Austin Company, of Cleveland, Ohio, a company that specialises in the design and construction of commercial and industrial buildings. Several interesting full-scale beam tests were conducted recently by the research division of the company at Euclid, Ohio. The prestressed concrete members tested to destruction were, respectively, a 40ft long I-beam and a 60ft long T-girder. The 40ft beam and the 60ft girder were chosen because of the general acceptance in the United States of 40ft and 60ft column spacing as the desirable minimum. Primarily, the tests were made to gain first-hand knowledge about practical construction problems, such as the use of low-slump, high-early-strength concrete; the handling, cutting and placing of high-strength prestressing steel wires, and the use of vibrators. The tests were also intended to establish confidence in the use of prestressing methods, materials and equipment. The 40ft beam, designated "F-40," was designed by the Freyssinet Company of New York. The dimensions of the I-section at mid-span were: depth, 26in; top flange, 18in wide and 5in thick at the edges; web, 5in thick, and bottom flange, 12in wide and 4in thick at its edges. The beam was reinforced with forty-eight wires, in four cables of twelve 0·192in diameter wires, having an ultimate tensile strength of 230,000 lb per square inch. Each of the cables was grouted in a 1in flexible steel conduit. Test loads were applied at approximate one-quarter points by means of hydraulic jacks. Between load points, ¼in diameter mild steel reinforcement was spaced at 12in centres, and six ¼in diameter longitudinal bars of mild steel were placed in the top and bottom of the beam.



60-FT PRESTRESSED CONCRETE GIRDER UNDER TEST

The beam was designed to carry 15,000 lb at each load point, based on a 5000 lb per square inch concrete and a 120,000 lb per square inch working stress in the prestress wires after relaxation. Under test, the first hair-cracks appeared at a load of 70,000 lb and rupture took place at a load in excess of 117,000 lb and a deflection of over 4in. The beam showed a deflection of $2\frac{7}{16}$in under a 99,000 lb load, but recovered all but ¼in when the load was removed. With the load off, hair-cracks, which had developed above 70,000 lb, disappeared.

The 60ft girder, designated "F-60," had a modified T-section and was also designed by the Freyssinet Company. At mid-span, the girder was 40in deep; its top flange was 30in wide and 5in thick, and its web 6in thick, widened to 12in for the bottom 7in. The reinforcement consisted of ninety-six 0·192in diameter wires, having an ultimate tensile strength of 210,000 lb per square inch, in eight cables of twelve wires each. Between the load points, ¼in diameter mild steel stirrups were placed at 12in centres and four ⅜in diameter and eight ¼in diameter longitudinal bars were placed; six in the top and six in the bottom of the beam. Test loads were applied at approximately one-third points. The girder was designed for a load of 25,000 lb at each load point, based on a 5000 lb per square inch concrete and a 120,000 lb per square inch working stress in the wires after relaxation. Under test, this girder broke under a load of 200,000 lb when the concrete under one of the jacks, which was applying the load, crushed enough top-flange concrete to cause failure. The girder, illustrated above, showed a central deflection of 22in before it finally collapsed.

Industrial and Labour Notes

Employment and Unemployment

The latest figures from the Ministry of Labour on the employment situation in Great Britain relate to the end of October. The working population then totalled 23,479,000 (16,034,000 men and 7,445,000 women), which was 3000 less than at the end of September. The total included 844,000 men and women serving in H.M. Forces.

The number engaged in civil employment at the end of October was 22,350,000, a total 49,000 (20,000 men and 29,000 women) less than that returned for the end of September. The biggest decline in civil employment in October was in the basic industries, which lost 34,000 during the month. It should be noted, however, that there were 31,000 fewer people employed in agriculture and fishing, which represented a seasonal decline. Coal mining manpower in October fell by 1000 to 694,000, and manpower in the gas, electricity and water supply services increased by 1000 to 366,000. The total number at work in the basic industries at the end of October was 4,157,000. The total for the manufacturing industries, 8,746,000, at the end of October was the same as that returned a month earlier, but in this group of industries there were several changes. Decreases were reported from the textiles and clothing trades, but the "metals, engineering and vehicles" group reported an addition to its manpower of 21,000, and by the end of October was employing 4,171,000 people, compared with 4,086,000 at the end of last year. Dealing with other industries and services, the Ministry's report notes a decline of 4000 during October in the number engaged in building and contracting, and a decline of 11,000 in the number of people engaged in professional, financial and miscellaneous services.

Unemployment figures given in the report show the position on November 12th, when 290,477 people were registered as out of work, compared with 263,756 on October 15th. The November figure included 162,946 men of eighteen and over, 15,661 of whom were described as "temporarily stopped."

Britain's Overseas Trade

Provisional figures of Britain's trade in November—which were issued by the Board of Trade at the end of last week—show that exports reached a record value of £243,800,000, which was £8,600,000 above the value achieved in October. There were twenty-six working days in November, compared with twenty-seven in October. The Board of Trade says that, taking the first eleven months of this year, exports have been at an annual rate of £2,591,300,000, or 19 per cent above the total for last year.

The value of imports during November was also high, the provisional figure being £328,800,000, compared with a monthly average of £327,800,000 in the period January to October inclusive. During the eleven completed months of this year the value of imports has been at a rate 51 per cent above the monthly average for 1950. Re-exports in November have been valued at £10,100,000. The excess of imports (valued c.i.f.) over exports and re-exports (valued f.o.b.) in the period January to November was £1,113,000,000, against £356,000,000 in the whole of 1950.

Non-Ferrous Scrap Prices

The Minister of Supply has made an Order, entitled the Non-Ferrous Metals Prices (No. 9) Order, 1951, by which the price of secondary unwrought copper has been brought under control and the controlled prices of secondary copper alloys have been reduced. The Order came into operation on December 12th.

The unwrought copper prices are now equivalent to the Ministry of Materials' selling price for virgin copper, and to permit the production of refined copper at those prices, the prices of copper scrap have been reduced by £8 per ton. Prices of copper alloy scrap have been reduced in proportion to the copper content. The new prices for the principal descriptions of secondary unwrought copper range from £224 to £225 10s. a ton. The new prices for brass are from £219 to £235 a ton, and the prices of copper scrap range from £166 a ton for braziery scrap to £202 a ton for clean bright, untinned or tinned copper wire, commutator bar, and firebox scrap which is cut to crucible size. The price reductions specified in the Order include, of course, those for Admiralty and commercial gunmetal scrap, cupro-nickel scrap, gilding metal scrap, and brass scrap.

The Order contains a provision permitting contracts already entered into at higher prices to be completed within a certain time, and also permitting additions for special shapes. In announcing the price changes, the Ministry of Supply has emphasised the paramount need for scrap metal at the present time and has expressed the hope that industry will continue to co-operate in the speedy return of scrap for re-use.

Trade Union Finance

In the December issue of *Labour*, the official bulletin of the Trades Union Congress, some observations are made about the high post-war level of British trade union membership and the soundness of the unions' financial position. What counts now, the T.U.C. says, is how the unions use their power and their purse. The yearly summary of trade union membership—referred to in these notes in our last issue—indicates the numerical progress made by registered trade unions in the last ten years or so. The T.U.C. says that full employment has made its mark on the figures. Since 1940 union membership has risen by one-third and income by two-thirds, while payments to unemployed have gone down to one-fifth.

But, the T.U.C. points out, much more is now being paid out in sickness benefit, and the suggestion is made that, although there are now more members to receive it, "that is not the whole story!" Nevertheless, the bulletin comments, there are indications that many unions have well-nourished treasuries. A summary of the funds held by registered trade unions at the end of each year shows that since 1940 they have been mounting steadily until the grand total to-day is over £62,000,000, or two and a half times as great as the sum recorded ten years ago. Part of those vast resources is no doubt pledged to the payment of cash benefits which may be drawn by members in years to come, but, the T.U.C. observes, the main weight of the evidence supports the view that the advance of the trade union movement as a whole is no longer handicapped by poverty. The bulletin goes on to suggest that worthwhile investments are not hard to find. Education, it says, is one, and research is another, as it claims that trade unions cannot know too much about the industries in which their members earn their living. A third "investment" mentioned is the training of specialists "to keep the trade union movement as up to date as management in the techniques of work study, production engineering, incentive payments, and the like."

Northern Ireland's Economic Problems

In a recent review of the economic position of Northern Ireland, Sir Basil Brooke, the Prime Minister, said that, in the last nineteen years 144 industrial undertakings had been established or expanded with Government financial assistance and they were now providing work for more than 20,000 people. Twenty-one factories had been built with a total floor area of over 1,000,000 square feet.

Sir Basil stated that seventeen additional factories, with a total floor area of approximately 840,000 square feet, were either under construction or were in the planning stage. Five of them were for particular firms and twelve were "advance" factories which had been planned in the hope of attracting industrialists. Sir Basil added that, whilst the situation in heavy engineering and shipbuilding appeared to be reasonably satisfactory in Northern Ireland, the position in the textiles and clothing industries were disturbing. Dealing with rearmament, he said that a number of contracts had been given to Northern Ireland firms and others were under discussion. But, Sir Basil suggested, for small engineering firms the main hope of employment lay in sub-contracting. He announced that a technical officer would shortly take up duty in Northern Ireland to help to fit smaller firms into the re-armament programme.

The Coal Situation

In recent weeks there has been a steady improvement in the output of coal from British mines. According to reports by the Ministry of Fuel and Power, total coal production in the first forty-nine weeks of this year has amounted to 210,234,200 tons, or just over 5,500,000 tons more than in the corresponding period of 1950. In the week ended December 8th output from the deep mines was 4,522,400 tons and from opencast workings 210,500 tons, making a total of 4,732,900 tons. In the comparable week of last year total output was 4,577,100 tons.

The Ministry's report shows that inland coal consumption in the first forty-eight weeks of this year, up to December 1st, totalled 190,878,000 tons, against 184,378,000 tons in the comparable period of 1950. The amount of coal taken this year for exports and bunkers, however, has been considerably reduced, with the result that in the first forty-eight weeks of this year inland and export requirements together added up to 201,596,000 tons, or just over 1,000,000 tons more than in the corresponding weeks of last year. On December 1st, distributed stocks of coal totalled 17,174,000 tons, compared with 14,766,000 tons on December 2, 1950.

In the week ended December 1st there was a small increase in the number of men working in the mines. The total on colliery books in that week was 695,800, of whom 286,200 were face workers. The number of shifts worked per wage-earner that week was 5·20, and the output per manshift at the face was 3·19 tons. Total absenteeism in the same week was 10·59 per cent, or just about the same as it was a year earlier.

Industrial Progress in Scotland

The annual meeting of the Scottish Council (Development and Industry) was held in Edinburgh on Friday last, and at it Lord Bilsland was re-elected president. Speaking at the meeting, Lord Bilsland directed attention to the increasing competition for skilled labour, and emphasised the need for maintaining export business. He also announced that negotiations were proceeding with a number of major British and North American companies, which, at the Council's suggestion, were considering production in Scotland. Almost all the companies, Lord Bilsland said, were concerned with electronics, precision engineering, chemicals, and similar industries and could make an important contribution to the promotion of the group development schemes which had been the Council's major industrial aim during the past year. Lord Bilsland added that the Scottish Council was proud of its share in attracting to Scotland over 80 per cent of all the North American companies which had established manufacturing plants in the United Kingdom since the war.

Notes and Memoranda

Rail and Road

EXHIBITION AT DERBY LOCOMOTIVE WORKS.—An exhibition for the promotion of accident prevention and safety for workers recently held at Derby Locomotive Works, was the first of its kind arranged by British Railways. Exhibits were divided into sections dealing with the works' medical and accident service, workshop exhibits, fire prevention, electrical hazards, the protection of eyes, and respiratory safeguards. There were also sections consisting of exhibits from industrial firms specialising in machine guarding and in safety footwear, and from the Safety and Welfare Museum, Horseferry Road, London.

Air and Water

BRIDGES OVER RIVER TAMAR.—The Minister of Transport recently received a deputation from the Cornwall County Council, the Plymouth City Council and the Saltash Borough Council, to discuss the questions of the construction of a high-level bridge over the River Tamar at Saltash and the provision of a third floating bridge for the Torpoint Ferry. It was agreed that the construction of the high-level bridge had to be regarded as a long-term project, but the Minister undertook to examine the deputation's representations in favour of carrying out a limited amount of preliminary survey work in the near future to fix the site of the bridge. About the provision of the third floating bridge the Minister expressed sympathy with the present conditions of congestion, but pointed out the difficulties arising from the restrictions on capital investment necessary to conserve labour and materials, particularly steel.

Miscellanea

THE LATE MR. C. H. PARKER.—We have learned with regret of the death of Mr. Charles Henry Parker, F.C.S., which occurred suddenly at Bournemouth on December 15th. Mr. Parker, who was seventy-eight, was chairman of Fordham Pressings, Ltd., Dudley Road, Wolverhampton, and a director of Coalite Chemical Products, Ltd.

"MEETING THE FUEL AND POWER SHORTAGE."—The Combustion Engineering Association states that the proceedings of its conference on "Meeting the Fuel and Power Shortage," held in London on October 9th and 10th, have been published. Copies may be obtained from the Association, 6, Duke Street, London, S.W.1, at 10s. 6d. each.

SWEDISH IRON PRICES.—According to a report by the Swedish Iron Works Association, the home prices of commercial iron in Sweden have increased by 31 per cent since the beginning of this year, though they are still below the prices of imported iron. It is stated that the increases were caused by higher costs for raw materials and wages.

THE ROYAL SOCIETY.—Professor E. D. Adrian, O.M., has been elected president of the Royal Society for the ensuing year. Sir Thomas Merton has been elected treasurer and vice-president; Sir Edward Salisbury and Sir David Brunt are secretaries and vice-presidents, and Sir Cyril Hinshelwood has been elected the Society's foreign secretary.

THE CORROSION OF METALS.—A course of evening lectures on "The Corrosion of Metals," is to be delivered at the Northampton Polytechnic, St. John Street, London, E.C.1, on Tuesdays at 7 p.m., beginning on January 15th next. The lecturer will be Mr. S. C. Britton, M.A., of the Tin Research Institute, and the course will extend over five weeks. The fee for the course is £1.

RE-EQUIPMENT OF INDUSTRY IN NORTHERN IRELAND.—Under the Re-equipment of Industry Act, by which it furnishes grants for re-equipping factories, the Northern Ireland Government had, by October 31st last, received sixty-one applications, involving an expenditure of almost £3,000,000. Of these, eighteen applications have been approved, and it is estimated that, for a start, grants up to £300,000 will be paid within the next six months.

THE ROYAL AGRICULTURAL SOCIETY.—At the recent annual general meeting of the Royal Agricultural Society of England, the retiring president, Lieut.-Colonel H. J. Cator, stated that there would probably be some profit on this year's Royal Show, which was held at Cambridge. The council's annual report states that, on October 10, 1951, the number of governors and members on the Society's register was 18,613, compared with 17,372 a year earlier. Earl Fortescue, K.G., has been elected president for the year 1951–52. Next year's Royal Show is to be held at Newton Abbot from Tuesday to Friday, July 1st to 4th.

IDENTIFICATION OF ALUMINIUM CASTING ALLOYS.—ALAR, Ltd., 3, Albemarle Street, London, W.1, has issued a new data sheet entitled "Colour Scheme for the Identification of Aluminium Casting Alloys," which is available upon request. The data sheet gives a list of colours or combination of colours for different alloy groups which are linked with B.S. 1490 Alloy Specification, and also the old designation.

ALUMINIUM ALLOY FORGINGS.—High Duty Alloys Ltd., has issued a booklet entitled *Aluminium Alloy Forgings—A Note on Progress*, by C. Wilson. The early alloys are noted and lists given of the aluminium alloy forgings for structural use and also of the alloys for high temperature use. Pre-forging and die-forging are generally discussed and these notes are followed by a reference to heat treatment of forgings and future trends.

TIN AND ITS USES.—The latest issue of the Tin Research Institute's journal mentions that a discovery in the Institute's metallurgical laboratory has made possible a form of pewter alloy that is soft while being spun but can afterwards be heat treated and hardened so that it keeps its shape in use. It is also shown how tin-zinc alloy (80 per cent tin) applied as an electroplate on steel bolts has been found successful in reducing corroaive action when bolts are fixed in aluminium structures.

WELDING DESIGN AND ENGINEERING.—The British Welding Research Association is arranging another summer school at Ashorne Hill, near Leamington Spa, from Wednesday to Friday, July 16 to 25, 1952, on "Welding Design and Engineering." The first part of the school, from July 16th to 20th, will be for those concerned with the purely practical aspects of welding and the second part, from July 20th to 25th, for those concerned with design, inspection and manufacturing problems. Further details will be announced in due course.

LECTURES ON PRESTRESSED CONCRETE.—The London County Council Brixton School of Building, Ferndale Road, S.W.4, has announced courses of adult and post-advanced courses of lectures on "Prestressed Concrete." There are to be twelve weekly lectures and demonstrations by Dr. P. W. Abeles, M.I.Struct.E., on Wednesday evenings at 6.30 p.m., beginning January 9th, and a tutorial class which will meet for six Monday evenings, at 6.30 p.m., from February 4th. At the latter, Mr E. W. Bennet, A.M.I.C.E., will lecture. The fee for the course of lectures is £2 and for the tutorial class meetings 10s.

SYMPOSIUM ON THE CHEMISTRY OF CEMENT.—The third international symposium on "The Chemistry of Cement" will be held in London, from September 15 to 20, 1952, and will be organised jointly by the Building Research Station of the Department of Scientific and Industrial Research, and the Cement and Concrete Association. Previous symposia were held in Stockholm in 1938 and London in 1919. The present tentative programme provides for more than twenty papers to be presented to the meetings under the general headings of constitution of Portland cement, the setting and hardening of Portland cement, special cements, and applications of research. During the course of the symposium visits will be arranged to places of interest. It is stated that because of the specialised nature of the symposium, attendance will be by invitation only. Further particulars are available from the Division of Building Research of the National Research Council, Ottawa, Canada.

INERT GAS WELDING.—A sound and colour film, entitled "The Argonarc Welding Process," has been produced recently for the British Oxygen Company, Ltd. There are two reels, the first of which deals with the equipment and application of the process in industry and the second with the use of Argonarc welding of aluminium and its alloys. In the first part a high-speed sequence gives a comparison between the characteristics of gas welding with flux on light alloys and electric welding with an inert gas shield. The weld pool under the gas flame is shown completely molten but unable to fuse due to the scaling effect of the oxide skin, which is unaffected by heat or mechanical disturbance, and to effect fusion flux is required plus the puddling motion of the filler rod. The film shows that when welding light alloys the flux residue, which is corrosive, must be removed and that where the joints are not accessible fluxless welding is a necessity. The function of the argon gas shield is explained by animated diagrams and the equipment for the various torch capacities is shown, together with a sequence of operations for hand and machine welds. The latest development of the process known as "Argonaut," which uses a pistol-shaped torch, is shown. The tungsten electrode of the "Argonarc" method is replaced by a consumable electrode, which is the filler rod, and which is automatically fed through the gun at the required rate. The electrical forces in the arc enable welds to be made in all positions. By use of the high-speed camera the necessity for particular arc characteristics for light alloy welding is shown. Animated diagrams illustrate the effects of using direct current. With the electrode positive the oxide film on the metal is broken up but ion bombardment overheats the electrode while, with reversed polarity, lack of emission from the work leaves the oxide film practically intact. Other diagrams show that by using alternating current the electrode is kept cool and that the introduction of a suppressor allows rhythmic and symmetrical arc action by correcting the partial rectification and thus eliminating the d.c. component. The effect of the argon shroud is observed by temporarily blowing away this protective screen, the metal is seen to oxidise immediately and when the argon shroud returns the oxide is quickly dispersed.

HEAVY OIL ENGINE WORKING COSTS.—The Working Costs Committee of the Diesel Engine Users Association presented its report on Heavy Oil Engine Working Costs (1949–50) at a meeting on December 13th. Certain modifications in presentation are noted and the number of returns is given as seventy-one compared with sixty-eight in the last report. Following the definition of the terms used are a series of notes and comments received from members. Six charts present graphically a comparison of the consumption and costs between the different stations with reference to certain of the tabular statements included in the report. The tabular statements give engine costs per unit generated for home and overseas stations and also average long period costs, while another table lists waterworks engine costs. The technical details of stationary mechanical injection and air injection engines are given in two sections in one table, and the final table lists the technical details of marine engine performance.

Personal and Business

SIR HUGH BEAVER has been appointed a member of the Colonial Development Corporation.

MR. PERCY G. CLADISH has been appointed sales manager of Brockhouse Engineering (Southport), Ltd.

MR. R. D. BROWN, A.M.I.C.E., has been appointed sales manager of Richard Sutcliffe, Ltd., Horbury, Wakefield.

MR. A. C. COOPER has been appointed acting sales manager of I.T.D., Ltd., and has taken charge of its home and overseas business.

ROURAFRIC AND FAR EASTERN, Ltd., has changed its address to Plantation House, Fenchurch Street, London, E.C.3 (telephone, Mansion House 1214).

MR. HUGH BECK, A.M.I.Mech.E., M.I.Mar.E., London manager of Crossley Brothers, Ltd., Openshaw, Manchester, has been appointed a director of the company.

MR. BERTRAM NELSON has been elected a member of the Mersey Docks and Harbour Board in succession to Lieut.-Colonel A. Buckley, who is not seeking re-election.

MR. A. R. COOPER, A.M.I.E.E., M.Inst.F., has been appointed Controller of the North-Western Generation Division of the British Electricity Authority, in succession to the late Mr. C. T. S. Arnett.

NEWALL GROUP SALES, Ltd., states that Mr. D. P. Roberts has been appointed its Birmingham area representative. His address is 77, Haunch Lane, King's Heath, Birmingham, 14 (telephone, Highbury 3360).

STANDARD TELEPHONES AND CABLES, Ltd., announces that the London sales office and warehouse of its rubber and plastic cables division has been transferred to new premises at 48, North Row, Mayfair, W.1 (telephone, Mayfair 4392).

THE RAILWAY EXECUTIVE announces the following appointments:—Mr. J. Holden Fraser, A.M.I.C.E., chief officer, engineering (signal and telecommunications) at headquarters; Mr. W. J. Garrod, assistant to executive officer (mineral traffic) at headquarters.

E. K. COLE, Ltd., Southend-on-Sea, states that Mr. Frank S. Allen, Mr. J. Corbishley, and Mr. A. W. Martin have been appointed directors, and that Mr. G. W. Godfrey, Mr. David Radford, and Mr. W. M. York have been appointed executive directors.

British Patent Specifications

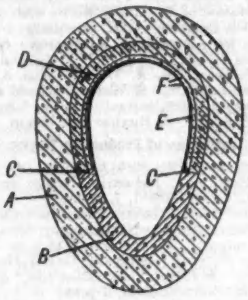
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

CIVIL ENGINEERING

659,790. March 7, 1949.—Sewers, Drain and Water Conduits, Francis James Patrick Lilley, 16, Larch Road, Dumbreck, Glasgow, Scotland.

The invention provides a method of repairing or strengthening damaged or defective sewers or conduits which does not necessitate the uncovering of the defective part and which will not interrupt the flow through the sewer or conduit while it is being repaired or strengthened. In the drawing, the conduit *A* is of egg-shaped cross section but it may be of circular or other section. To repair or strengthen a damaged conduit one or more precast concrete segments *B* of a shape similar to the lower part of the conduit are introduced. Each segment is of such a length that it can be easily man-handled within the conduit.



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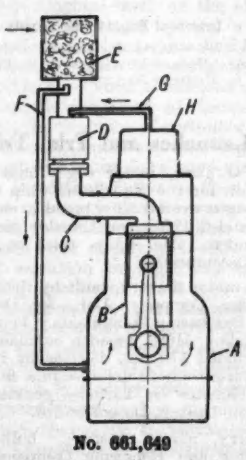
The two longitudinal edges of the segments are provided with "V" or other channels *C*, into which are introduced the ends of reinforcing metal mesh *D* bent to conform with, but spaced apart from, the wall of the upper part of the conduit. Secured by tie wires to the reinforcing mesh but spaced therefrom is a finer mesh *E* bent to conform to the internal face of the lining to be applied. Concrete *F* is then introduced by means of an air gun to fill the cavity between the damaged or defective wall and the reinforcing mesh and between it and the mesh forming the internal face. A fine skin of concrete can then be applied to the internal face.—*October* 24, 1951.

INTERNAL COMBUSTION ENGINES

661,649. December 13, 1949.—Ventilation of Internal Combustion Engine Crankcases, Conrad Allan Cook, of F. J. Cleveland and Co., of 29, Southampton Buildings, Chancery Lane, London, W.C.2. (*Communicated by Fiat Societa Per Azioni, of* 300, *Corso IV Novembre, Turin, Italy.*)

The invention affords the advantage of avoiding a crankcase breather for the inlet of the ventilating air and the need of a special cleaner for the air.



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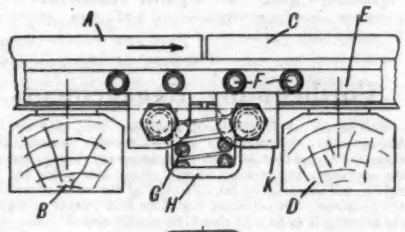
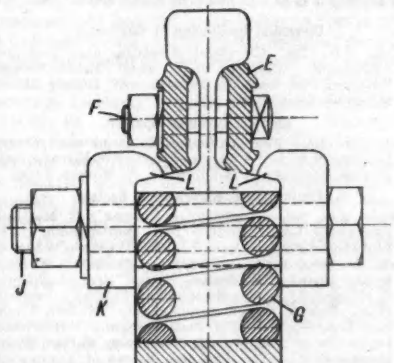
In the accompanying drawing *A* is the crankcase of an internal combustion engine *B*, the cylinder *C* is the suction manifold and *D* the carburetter which receives cleaned air through the filter *E*. A pipe *F* is interposed in the air inlet pipe connecting the cleaner with the carburetter and has an end turned towards the air cleaner. This pipe connects the air inlet pipe with the lower portion of the crankcase. A further pipe *G* in the air inlet pipe has an end turned towards the carburetter and connects the air inlet pipe with the head *H* of the casing enclosing the engine. The system described establishes a ventilating air circuit, the air being filtered through the cleaner and flowing as indicated by the arrows through the pipe *F* to the crankcase *A* up to the head *H* and through pipe *G* back to the air inlet pipe. The arrangement of the two pipe ends, described above, is such as to set up a pressure zone at the upper end and an underpressure zone at the other end in order to ensure circulation of the air.—*November* 21, 1951.

RAILWAY ENGINEERING

661,625. June 21, 1949.—Rail Joint, James Buchanan Lings, Bank Chambers, 329, High Holborn, London, W.C.1. *Communicated to him by Bubal A.G., of* 128, *Gartenstrasse, Basle, Switzerland.*

Referring to the drawing, the end *A* of one rail rests on a sleeper *B* and the end *C* of the succeeding rail on a sleeper *D*. The two ends are joined together by side fish plates *E* and bolts *F*. In addition, the rails are also joined together by a spring assembly beneath them. It comprises a prestressed compression spring *G*, which rests on a counter support and is pressed against the soles of the two rails by a prestressing force of, for example, 15 tons. The counter support comprises a stirrup *H* on which the





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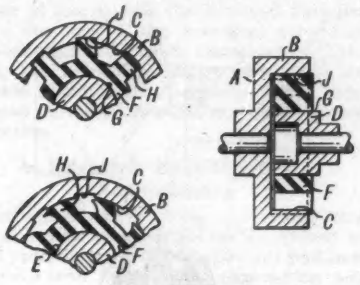
spring directly rests. The stirrup has at each end an eye through which a bearing bolt *J* passes. The bolt is supported in the bore of carrier brackets *K* on each side of the rail engaging with a nose *L* over the foot of the ends of the rails. When rolling stock passes over the rail joint in the direction of the arrow the wheel pressure first causes the end *A* of the rail to sink. This movement is transmitted by the spring to its counter support to the end *C* of the succeeding rail. With suitable prestressing of the spring the end of the succeeding rail is depressed by the transmitted force by the same amount as the end of the preceding rail, so that no, or practically no, difference in height arises between the ends of the two rails.—*November* 21, 1951.

POWER TRANSMISSION

661,643. November 14, 1949.—Shaft Couplings, Stanley Morton, 3370, West Forty-third Avenue, Vancouver, British Columbia, Canada.

The invention provides a shaft coupling which releases when overloaded, and returns to and remains in its normal position when normal load conditions are restored. As shown in the drawings, the coupling is made in two parts connected to the shafts, which are to be coupled together. One part is formed with a plate *A* having a hub into which the end of the shaft is fixed. An annular flange *B* projects outwards from the plate and has an inner bearing surface *C*. The other part of the coupling consists of a drum *D* which fits inside the flange *B*, the drum having an outer bearing surface *E* spaced from and concentric with the inner surface of the flange. It is provided with an outwardly projecting hub in which the shaft is fixed. The flange *B* and drum *D* constitute the driving and driven elements. In this example, however, the drum is considered the driving element. A member *F* formed of suitable deformable material, such as rubber, is mounted between the elements *B* and *D*. It is in the form of a sleeve which is pressed on and/or bonded to the surface *G* of the drum, and has projections *H* which fit into shallow recesses *J* formed in the surface of the annular flange *B*. The outer ends of these projections and the recesses may be rectangular or curved in shape. The top



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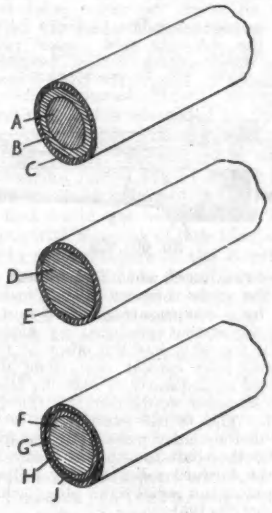
left-hand view shows the coupling under normal load conditions. When the drum is rotated, the movement is transferred through the member *F* and its projections to the flange *B*. The projections are stiff enough to make a driving connection between the two elements under normal conditions. If an overload is placed on either of the shafts the projections *H* are deformed and bend, to permit one element to move in relation to the other, as shown in the lower left-hand view. As long as the overload condition remains, one element will turn in relation to the other, but when normal conditions are restored, this movement will continue only until the projections snap into the recesses, at which time the elements will turn together.—*November* 21, 1951.

ELECTRICAL ENGINEERING

659,977. October 14, 1949.—Electrical Conductors, The British Thomson-Houston Company, Ltd., of Crown House, Aldwych, London, W.C.2.

This invention relates to electrical conductors and particularly is concerned with electrical conductors comprising a metallic core, the outer surface of which is an aluminium compound selected from the class consisting of aluminium, aluminium oxide and



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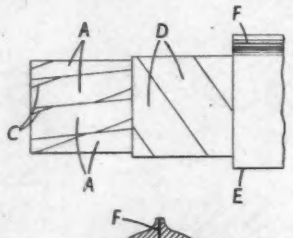
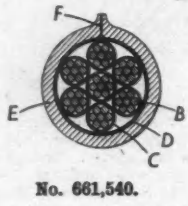
aluminium fluoride; and an outer sheath comprising polymeric chlorotrifluoroethylene superimposed directly on the core. The accompanying drawing shows three figures, which are perspective views of insulated electrical conductors embodying the invention. The upper view shows a metallic core *A* of copper, surrounded by a thin adherent coating of aluminium *B* and superimposed directly on the aluminium coating is a synthetic resinous insulation material comprising polymeric chlorotrifluoroethylene *C*. In the middle view the electrical core *D* is essentially of aluminium, surrounded by a coating of polymeric chlorotrifluoroethylene *E*. The lower view shows a copper core *F* having a thin adherent

film of aluminium *G* which in turn has a thin film of aluminium oxide *H*. Polymeric chlorotrifluoroethylene insulation *J* covers the aluminium oxide film. In the specification the preparation of the material and the manufacture of these electrical conductors is fully described.—*October* 31, 1951.

661,540. November 2, 1949.—Electric Cables, Pirelli-General Cable Works, Ltd., of 343–5, Euston Road, London, N.W.1; and Bertram Owen Ashford, of the company's address.

Referring to the drawings, which are made to an enlarged scale, there are seven cores *A*, each comprising the stranded conductors *B* of copper wires, around which is wound a tape *C* of mineral insulating





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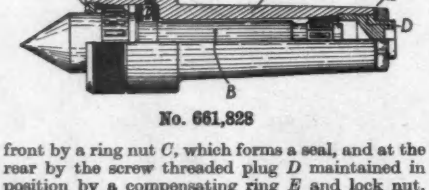
material; the cores are enclosed in a wrapping *D* of heat-resisting dielectric material consisting of a mineral insulation in tape form, helically lapped around the cores. The wrapped cores are finally enclosed in an external metal sheath *E* made by folding a strip of aluminium or other suitable metal around the wrapped cores and then welding together the edges of the strip so as to form a longitudinal welded seam *F*. The external sheath of the cable may be of any metal or alloy, such as aluminium, copper or stainless steel, which can be joined longitudinally to form a continuous tube by welding.—*November* 21, 1951.

WORKSHOP TOOLS AND APPLIANCES

661,828. September 1, 1949.—Rotating Centre Point for a Lathe Poppet Head, Henry Conrad Heide, 2, Broad Street Buildings, Liverpool Street, London, E.C.2. (*Communicated from Andre Joseph Chevallay, of* 6, *Rue Lefebvre, Paris* 15e, *France.*)

As shown in the drawings, the body *A* has a shaft *B* on which the centre point is mounted through a pair of roller bearings. The rollers turn in the obliquely split conical rings which bear on corresponding conical bearing surfaces formed inside the body. The body is closed at the



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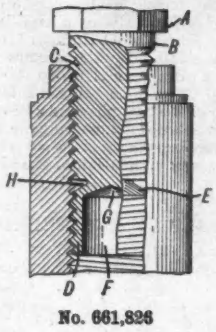
front by a ring nut *C*, which forms a seal, and at the rear by the screw threaded plug *D* maintained in position by a compensating ring *E* and lock nut. Locking adjustment produced by means of the nut or of the plug has the effect of forcing the appropriate split conical ring along its bearing surface and consequently of reducing the diameter so that accurate adjustment of the bearing is achieved. The thrust exerted by a workpiece bearing on the centre point of the shaft is transmitted by the shaft to the ball thrust bearing *F* behind the forward roller bearing. Opposite the thrust bearing is a radial screw plug for lubrication.—*November* 28, 1951.

MISCELLANEOUS

661,826. August 24, 1949.—Self Locking Screw, The Eaton Manufacturing Company, 739, East 140th Street, Cleveland, Ohio, U.S.A. (Assignees of Andrew Schneider).

This invention relates to locking screws and self-locking adjustment screws. Referring to the drawing, *A* represents generally a self-locking adjustment screw of the kind used with engine tappets. The shank *B* of the screw includes a pair of axially spaced equal pitch diameter threaded sections *C* and *D* integrally connected together by an unthreaded section *E* arranged concentrically. The lead of the thread on section *D* is axially offset to the lead of the thread on section *C* by a predetermined amount. The threaded section *D* of the screw is provided with an axial bore *F* terminating in a taper *G*. The screw has an annular groove *H* between the threaded sections, so as to provide, in conjunction with a taper, a section of conical shape. The threads on the sections *C*



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and *D* are rolled with the predetermined offset between them, positively establishing the desired offset at no load deflection of the diaphragm section *E*. Therefore with the proper determination of the torque holding qualities for a standard screw, a permissible torque range can be obtained even accounting for variations in machining inaccuracies of the screw and its associated internally threaded member. The offset between the sections is made either negative or positive, depending upon the required tensile or compressive holding application of the screw.—*November* 28, 1951.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME and PLACE at which the meeting is to be held should be clearly stated.

Cleveland Institution of Engineers

Mon., Jan. 7th.—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Recent Developments in American Rolling Mills," R. Stewartson, 6.30 p.m.

Electric Railway Society

Sat., Jan. 5th.—Fred Tallant Hall, Drummond Street, London, N.W.1, "A Pictorial Survey of Electric Railways in Holland and Belgium" G. W. Morant, 3 p.m.

Illuminating Engineering Society

Thurs., Jan. 3rd.—Nottingham Centre: E. Midlands Electricity Board, Smithy Row, Nottingham. "The Lighting of Modern Ocean Liners," T. Catten, 5.30 p.m.

Fri., Jan. 4th.—Bath and Bristol Centre: S.W. Electricity Board, Old Bridge, Bath, "Neon Lighting." C. Higgins, 7 p.m.——Birmingham Centre: Imperial Hotel, Temple Street, Birmingham, "Modern Transport Lighting," W. E. J. Drake, 6 p.m.——Huddersfield Group: Electricity Showroom, Market Street, Huddersfield, "The Use and Misuse of Fluorescent Lighting," T. C. Holdsworth, 7.15 p.m.

Incorporated Plant Engineers

Tues., Jan. 1st.—Institute of Engineers, Park Place, Cardiff, "Hard Surfacing with Stellite," 7.15 p.m.

Wed., Jan. 2nd.—Southampton Branch: Polygon Hotel, Southampton, Talk on the Application of the Factories Act, 7.30 p.m.

Thurs., Jan. 3rd.—Peterborough Branch: Eastern Gas Boards Demonstration Theatre, Church Street-Peterborough, "Power Distribution," G. J. Richardson, 7.30 p.m.

Institute of British Foundrymen

Sat., Jan. 5th.—Birmingham and W. Midlands Students' Section: Works visit to Round Oak Steel Works, Ltd., Brierley Hill, Staffs, 10 a.m.

Institution of Industrial Administration

Fri., Jan. 4th.—London Centre: Management House, Hill Street, W.1, annual general meeting, 7 p.m.

Institute of Marine Engineers

Tues., Jan. 8th.—85, The Minories, London, E.C.3, "Diesel-Hydraulic Propulsion," F. J. Mayor, 5.30 p.m.

Institute of Metals

Thurs., Jan. 3rd.—Visit to the Metallurgical Laboratories, Birmingham University, Birmingham, 15, discussion on "Tool and Die Materials for the Hot Working of Non-Ferrous Metals and Alloys," 2.30 p.m.——London Local Section: 4, Grosvenor Gardens, S.W.1, "Research on the Working of Metals," W. C. F. Hessenberg, 7 p.m.

Institute of Navigation

To-day, Dec. 21st.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Meteorology and Navigation," P. G. Satow, 5 p.m.

Institute of Road Transport Engineers

Fri., Jan. 4th.—Midlands Centre: Imperial Hotel, Temple Street, Birmingham, "Modern Transport Lighting," W. E. J. Drake, 6 p.m.

Institution of Civil Engineers

Tues., Jan. 1st.—Great George Street, Westminster, London, S.W.1, "Some Problems in the Disposal of Industrial Effluents and Domestic Wastes," J. T. Calvert and P. M. Amcotts, 5.30 p.m.

Institution of Electrical Engineers

Mon., Jan. 7th.—S. Midlands Centre: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Protection of Electrical Power Stations: A Critical Review of Present-Day Practice and Recent Progress," H. Leyburn and C. H. W. Lackey, 6 p.m.

Tues., Jan. 8th.—Measurements and Radio Section: Savoy Place, London, W.C.2, "Two Electronic Resistance or Conductance Meters," L. B. Turner: "A Bridge for the Measurement of the Dielectric Constants of Gases," W. F. Lovering and L. Wiltshire, 5.30 p.m.——N. Midland Centre: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "Crystal Diodes," R. W. Douglas and E. J. James, 6.30 p.m.

Institution of Mechanical Engineers

Tues., Jan. 1st.—Coventry A.D. Centre: Craven Arms Hotel, Coventry, "Shock Absorbers," J. W. Kinchin and C. R. Stock, 7.15 p.m.

Fri., Jan. 4th.—Storey's Gate, St. James's Park, London, S.W.1, "Some Considerations on Bogie Design, with Particular Reference to Electric Railways," W. S. Graff-Baker, 5.30 p.m.——N.E. Branch, Graduates' Section: Northern Gas Board Showrooms, Grainger Street, Newcastle upon Tyne, "Modern Large Turbo-Alternator Construction and Erection," W. G. Bryce.

Mon., Jan. 7th.—N.E. Branch: Neville Hall, Westgate Road, Newcastle upon Tyne, "The Measurement and Interpretation of Machinery Noise, with Special Reference to Oil Engines," C. H. Bradbury, 6 p.m.

Tues., Jan. 8th.—Automobile Division: Storey's Gate, St. James's Park, London, S.W.1, "Stability of Single-Track Vehicles," R. A. Wilson-Jones, 5.30 p.m.——S. Wales Branch: S. Wales Institute of Engineers, Park Place, Cardiff, annual meeting, "Some Fuel and Power Projects," H. Roxbee Cox, 6 p.m.

Institution of Production Engineers

Tues., Jan. 1st.—Reading Section: Great Western Hotel, Reading, "Industrial Design and the Engineer," K. L. Brookfield, 7.15 p.m.

Wed., Jan. 2nd.—Nottingham Section: Welbeck Hotel, Milton Street, Nottingham, "Cost Control in Engineering," L. W. Robson, 7.15 p.m.——Wolverhampton Section: Star and Garter Hotel, Wolverhampton, "Polished Plate Glass and 'Armourplate' Glass," film, Mr. Hatton, 7 p.m.

Thurs., Jan. 3rd.—London Section: Old Ship Hotel, Brighton, "Improvements and Their Hindrances," C. R. Whitaker, 7 p.m.

Mon., Jan. 7th.—Halifax Senior and Graduate Section: George Hotel, Huddersfield, "Steam Turbine Manufacture," A. C. Annis, 7.15 p.m.

Institution of Structural Engineers

Mon., Dec. 31st.—Midland Counties' Branch: James Watt Memorial Institute, Great Charles Street, Birmingham, Films, "Buildings of the South Bank Exhibition," "Prelude to Power: The Building of the Castelo Do Bode Dam, Lisbon," "H.M.S.O., Sighthill, Edinburgh," 7 p.m.

Junior Institution of Engineers

Fri., Dec. 28th.—39, Victoria Street, London, S.W.1, "Hydro-Electric Power Developments," J. Foster Petree, 6.30 p.m.

Wed., Jan. 2nd.—Midland Section: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Manufacture of Coins," G. H. Thompson, 7 p.m.

Fri., Jan. 4th.—39, Victoria Street, London, S.W.1, film evening, "Rocket Flight," introduced by S. G. Clark, 6.30 p.m.

Mon., Jan. 7th.—N.W. Section: Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, ordinary meeting, A. Eaton, chairman's address, 7.30 p.m.

Leeds Metallurgical Society

Thurs., Jan. 3rd.—The University, Leeds, "The Platinum Metals, their Properties and Uses," J. C. Chaston, 7 p.m.

Liverpool Engineering Society

Mon., Jan. 7th.—Royal Institution, Colquitt Street, Liverpool, "Modern Developments in Electric Welding," H. G. Taylor, 6.30 p.m.

Launches and Trial Trips

M.S.C. Quarry, motor tug; built by Henry Robb, Ltd., for the Manchester Ship Canal Company; length overall 95ft, breadth moulded 24ft, depth moulded 12ft; two Crossley diesel engines, four cylinders, 1200 b.h.p. total at 250 r.p.m. Launch, December 1st.

Ceara, motor tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Brazilian Tankers' Purchasing Commission; length between perpendiculars 510ft, breadth moulded 69ft 6in, depth moulded 37ft 3in, deadweight 16,500 tons; Barclay Curle-Doxford diesel engine, five cylinders, 670mm diameter by 2320mm combined stroke, 5600 b.h.p. Launch, December 3rd.

Seniority, motor coaster; built by Goole Shipbuilding and Repairing Company, Ltd., for F. T. Everard and Sons, Ltd.; length 225ft, breadth moulded 37ft 10in, depth moulded 16ft, deadweight 1815 tons; Newbury diesel engine, 800 b.h.p. at 250 r.p.m., speed 10½ knots. Trial, December 4th.